

# Solar energy, the source of energy and the savior of the earth



"If you want to find the secrets of the universe, think in terms of energy, frequency and vibration."

— **Nikola Tesla**

Energy, water and food are the three main elements to ensure human survival, which are interdependent. For example, if we have enough energy, we can provide more water and food. Since every tool and technology needs energy to do any type of work, knowing energy and its types, its correct use and application, and correct decisions in this field are essential. According to the analysis and data of the report of the International Energy Agency, solar energy will reach the first place as the most used source of energy by 2027. In addition, the sun is almost the main source of most of the other energies, whose detailed investigation leads to a deeper understanding that is more applicable to the development of new technologies. In this chapter, at first, the types of energy and their classification have been reviewed in summary form. Later, the main sources of generation and conversion of energy and solar energy are explained in detail. At the end, energy storage, transmission and distribution are briefly explained, which are important parts of new technologies.

## Contents

Types of energy and its sources.....	4
Classification of different types of energy.....	5
The main sources of energy extraction and the conversion of different types of energy into each other.....	8
Introduction.....	9
The main sources of energy extraction.....	9
Converting different types of energy into each other.....	12
Electricity.....	14
The sun and solar energy.....	17
The sun and solar radiation.....	24
Solar Energy.....	30
Solar energy technologies.....	34
Photovoltaic systems.....	36
Concentrated solar power (solar thermal power plant).....	42
Applications of solar energy.....	48
Photovoltaic installation.....	51
Solar economy.....	51
Solar utility scale.....	52
Residential solar.....	52
Combining electricity produced from photovoltaic solar energy with existing power plants.....	53
Wholesale and macro markets for solar energy.....	53
Establishing and using the technology of solar energy.....	54
A final approach.....	55
Transmission, storage and distribution of energy.....	56
Introduction.....	56
Energy Transmission.....	57
Energy storage.....	58

## Types of energy and its sources

Energy is the ability to work or bring about change. It exists in a wide range of forms, such as potential, kinetic, chemical, nuclear, and thermal. Energy can be transferred between objects and transformed into other forms, but it cannot be created or destroyed.

If we accept that existence consists of "matter" and "energy", then understanding matter seems relatively easier, because energy is one of the deep and complex concepts in all sciences. Unlike matter, energy cannot be smelled, seen or touched most of the time. Although most of us are familiar with energy, it is difficult to define because many forms of energy are not a smelly, visible, and tangible "thing" (in terms of having mass). On the other hand, the relationship between matter and energy makes this definition more difficult.

Perhaps, considering the scope of the book and the world of technology, it is better to use the concept of "work" to define energy, in which case it can be said that energy is equivalent to "the ability to do work"; which is one of the simplest definitions of energy in physics. This definition means that we need energy to do anything. It should be noted that work is not a form of energy, but a method of transferring energy from one point to another or converting it from one type to another. In this definition, energy is closely related to the concept of "force". In classical physics, force refers to the effect that objects can create and change in dynamics. Force is a vector quantity, meaning it has both magnitude and direction. According to a more general and of course more modern definition, there are four main types of interaction between bodies, which, in order of strength from high to low, include the following: strong nuclear force, electromagnetic force, weak nuclear force, gravitational force

Energy appears in various forms, which include: kinetic energy, thermal energy, electromagnetic radiation energy, gravitational potential energy, elasticity, electrical, chemical, nuclear and ionization energy.

Today, there are many energy sources available for harnessing and mining, each of which has its own advantages and disadvantages. These sources include the sun, wind, water, fossil fuels such as coal and oil and gas, radioactive elements such as uranium, geothermal and biomass, tides and oceans.

Understanding energy allows us to harness it responsibly for use in transportation, electricity, heating and industrial applications that power

economic growth and development. Optimizing energy efficiency and adopting green technologies are key to ensuring access to clean, affordable energy for the world's growing population. Managing energy consumption wisely today secures our energy supplies for the future.

## Classification of different types of energy



There are different classifications and separations for energy based on different aspects. They can be separated in terms of presence, environmental, sustainability, renewable, green and clean, and these divisions may have commonalities, similarities and differences. Not all renewable energy is sustainable energy and vice versa.

Excessive pollution of the environment due to the use of fossil fuels is one of the huge crises that can be solved with the introduction of new energy. Energy use is considered sustainable if it meets the needs of the present without compromising the needs of future generations. Definitions of sustainable energy typically include environmental aspects such as greenhouse gas emissions and social and economic aspects such as energy scarcity. Burning fossil fuels and biomass<sup>1</sup> is one of the main causes of air pollution, which causes thousands and even millions of people to die every year. There are still challenges to overcome in terms of cost, infrastructure and politics to develop sustainable energy.

to the useful energy obtained from renewable sources that do not involve carbon and are naturally charged and stored by nature in a short period of time, such as the sun, wind, rain, tides, waves and the heat of the earth's core, energy It is called renewable. On the other hand, there are non-renewable energies such as fossil fuels that take a long time to produce and pollute the environment due to the presence of carbon. These energy sources lead to environmental degradation and climate change due to their carbon-intensive nature and extraction processes. Many renewable energies are classified as sustainable energies, but some of them, such as biomass, are not considered sustainable because they pollute the environment.

Green energy usually refers to renewable energy sources that have the lowest environmental impact and do not result in carbon production. In addition to biomass, in the end even other renewable energies have losses for the environment. Green energy includes solar, wind, hydro and geothermal energy because they produce clean electricity and have a lower carbon footprint compared to conventional energy sources. It is important to note that there can be overlap and different perspectives in these classifications, as the assessment of energy resources may depend on specific contexts, technologies, and socio-economic factors.

The benefits of sustainable energy go beyond its renewables. Sustainable energy offers significant environmental benefits such as reduced greenhouse gas emissions and air pollution associated with traditional energy sources. In addition, sustainable energy sources are often more and

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<sup>1</sup> Biomass is plant or animal matter that is used as fuel to produce electricity or heat, for example wood, waste, etc.

better distributed, promoting energy independence and reducing the vulnerability of centralized power systems. To fully realize the potential of sustainable energy, advances in technology, infrastructure and policy support are essential. Continuous investment in research and development is necessary to improve efficiency, reduce costs and integrate different sustainable energy sources into the existing energy grid. Sustainable energy encompasses a wider scope that includes not only environmental aspects, but also socio-economic impacts and long-term resource management.

- Sustainable energy considers the entire life cycle of energy systems, taking into account factors such as resource extraction, production, distribution and end-of-life disposal. The program promotes holistic strategies for energy production, consumption and management to ensure a sustainable energy future.

- While green energy primarily focuses on reducing carbon emissions, sustainable energy considers other aspects of sustainability such as energy efficiency, biodiversity conservation, social equity and economic viability. Sustainable energy goes beyond renewable energy sources and also includes energy efficiency measures, energy saving practices and integration of energy systems that promote optimal use of resources and reduce losses and waste.

- Green energy is often marketed as a consumer choice or as a specific product such as purchasing green energy credits or installing solar panels. On the other hand, sustainable energy encompasses a wider dimension, including vision, including policy frameworks, technological developments, and systemic changes in the energy sector.

In short, green energy can be considered as a subset of sustainable energy with a special focus on carbon reduction and low or zero emissions. Sustainable energy is a multidimensional concept that integrates environmental, social and economic considerations in the planning and management of energy systems with the goal of long-term sustainability and resilience.



The main sources of energy extraction and the conversion of different types of energy into each other



## Introduction

Energy conversion plays a fundamental role in shaping our modern world, advances and drives our daily activities. Energy conversion has always been happening since billions of years ago, and today, by knowing these old natural processes, humans act in energy conversion for their own special and new purposes. The ability to efficiently convert one type of energy into another form is very important in many areas, including transportation, industry, and our personal lives. This process is important for several reasons. One of the main reasons lies in the finite nature of our energy resources. Energy conversion enables us to take advantage of different forms of energy and harness their potential effectively. Renewable energy sources have vast reserves that guarantee clean and long-term energy supply. By effectively converting these resources, we can reduce our carbon footprint, fight climate change and protect our planet for future generations. Energy conversion also has tangible benefits for transportation systems. Industry also relies heavily on energy conversion processes. Factories and facilities require significant amounts of energy to power their operations. Efficient energy conversion allows industries to minimize waste, optimize production and reduce energy consumption, contributing to economic and environmental sustainability. The use of cleaner energy sources in industrial processes reduces harmful emissions and ensures the well-being of surrounding communities. In addition, energy conversion has a very important impact on the daily life of humans. Many conveniences are made possible through energy conversion, from charging electronic devices to heating or cooling homes. Energy conversion technologies, such as solar panels or heat pumps, enable homeowners to generate their own electricity or use natural resources such as geothermal heat efficiently. This not only reduces energy costs, but also enables people to be active participants in the transition to a greener future.

As a result, energy conversion has an important place in our society and global development. By converting and optimizing different forms of energy, we can effectively address the challenges posed by limited resources, climate change, and unsustainable practices. This process is very important in achieving a stable, clean and prosperous future for yourself and future generations. In this section, the main sources of energy generation and the conversion of different types of these energies into each other have been examined.

## The main sources of energy extraction

The sun is actually the ultimate source of all forms of energy on Earth, except for nuclear and geothermal energy. Solar energy is harnessed on Earth through various methods. For example, solar panels, which consist of photovoltaic cells, absorb sunlight and convert it into electrical energy through the photovoltaic effect. This electrical energy can be used in different ways. In addition to the energy received directly from the sun (such as photovoltaics, concentrated solar power for heating, lighting, photocenters, passive solar design, etc., which are described below), solar energy indirectly generates energy from several sources. It provides other renewable energy and has already provided energy from non-renewable sources. For example, wind energy is produced when sunlight heats different parts of the Earth unevenly, causing changes in temperature and thus air pressure. These changes lead to the movement of air and the creation of wind, which can be used through wind turbines to generate electricity. Tidal energy occurs due to the effects of the gravitational forces of the moon and the sun on the earth. The sun's effect on tidal energy is indirect through its gravitational pull, which affects the height and timing of tides. The time required to transfer and create tidal and wind energy is approximately a few minutes to a few hours.

Similarly, hydroelectric power relies on solar energy. The sun evaporates water from oceans, lakes and rivers and forms clouds, which eventually lead to rain or snow. This accumulated water flows through rivers and streams, driving turbines and generating electricity as it passes through hydroelectric plants. This process takes several weeks to several months. Even fossil fuels such as coal, oil and natural gas are ultimately derived from solar energy. Millions of years ago, plants grew by absorbing sunlight through the process of photosynthesis. When these plants died and decomposed, they formed layers of organic matter that, over time, turned into fossil fuels through heat and pressure deep in the Earth's crust.

Only two sources of nuclear and geothermal energy, their main source is not the sun star. Nuclear energy is produced from radioactive elements such as uranium. The presence of radioactive elements such as uranium on Earth can be explained by the processes that occurred during the formation of the solar system. These elements were mainly produced during the supernova explosion of massive stars, about 6 to 7 billion years ago. This process, known as nucleosynthesis, involved the fusion of lighter elements such as hydrogen in the cores of stars to form heavier elements such as uranium, iron and other elements. Another energy of the earth, which existed at the same time as the formation of the sun and the solar system, is geothermal

energy. Earth's core is hot due to two reasons: residual heat from the formation of the planet and the decay of radioactive elements inside it. When Earth formed approximately 4.6 billion years ago, it underwent a process called accretion, in which smaller planetary bodies collided and merged, releasing significant amounts of energy. This process produced heat and caused the Earth to partially melt. Over time, as the planet continued to accret and gravitational forces compressed the core, the molten material solidified, but retained much of its initial heat. Another warming of the Earth's core is the decay of radioactive elements. Earth's core contains small amounts of radioactive elements such as uranium, thorium and potassium. These elements were present early in the formation of the Earth and are still subject to radioactive decay. During this process, the atomic nuclei of these elements break spontaneously and some of the initial mass is released as huge heat energy.

Figure 1 depicts how the energies are generated and transferred to the earth along with the required time and periods.

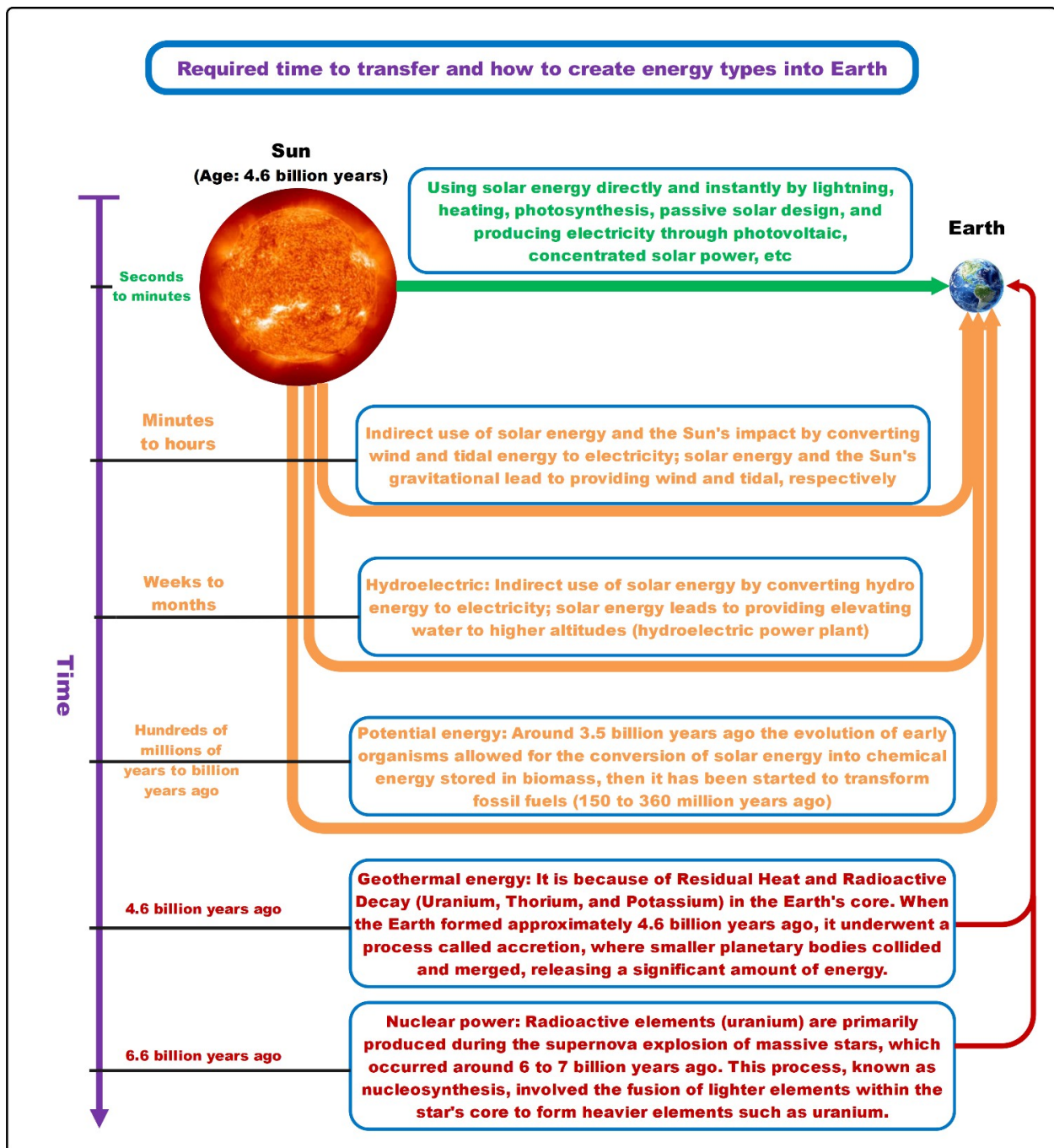


Figure 1: Creation and transferring energy to the earth

## Converting different types of energy into each other

In this section, the conversion of different types of energy to each other has been investigated, and all energies originate from the sun, except for nuclear and geothermal energy. In the universe, energy exists in different forms, which are shown in Figure 2, their conversion to each other. Different forms of energy are always transforming into each other, but the source of energy can be considered the sun, and the final destination of all of them is thermal energy. It can be seen that usually the chemical energy stored in fossil fuels is converted into thermal energy by burning, and the efficiency of these combustions is almost 90%. Thermal energy can be converted into mechanical energy using heat engines. Heat engines have an energy conversion efficiency of up to 60%. Their efficiency and efficiency are ultimately limited by Carnot's efficiency constraint, which is the principle that most current cars and heat engines work on. Mechanical energy can be converted into electricity using electric generators with an efficiency of up to 99%. Currently, most of the world's electricity is produced by a turbo-generator connected to a steam turbine (Rankin cycle), and the main source of steam turbine energy is mostly coal. During the process of generating electricity from fossil fuels, at least 50% of the primary chemical energy contained in these fuels is lost.

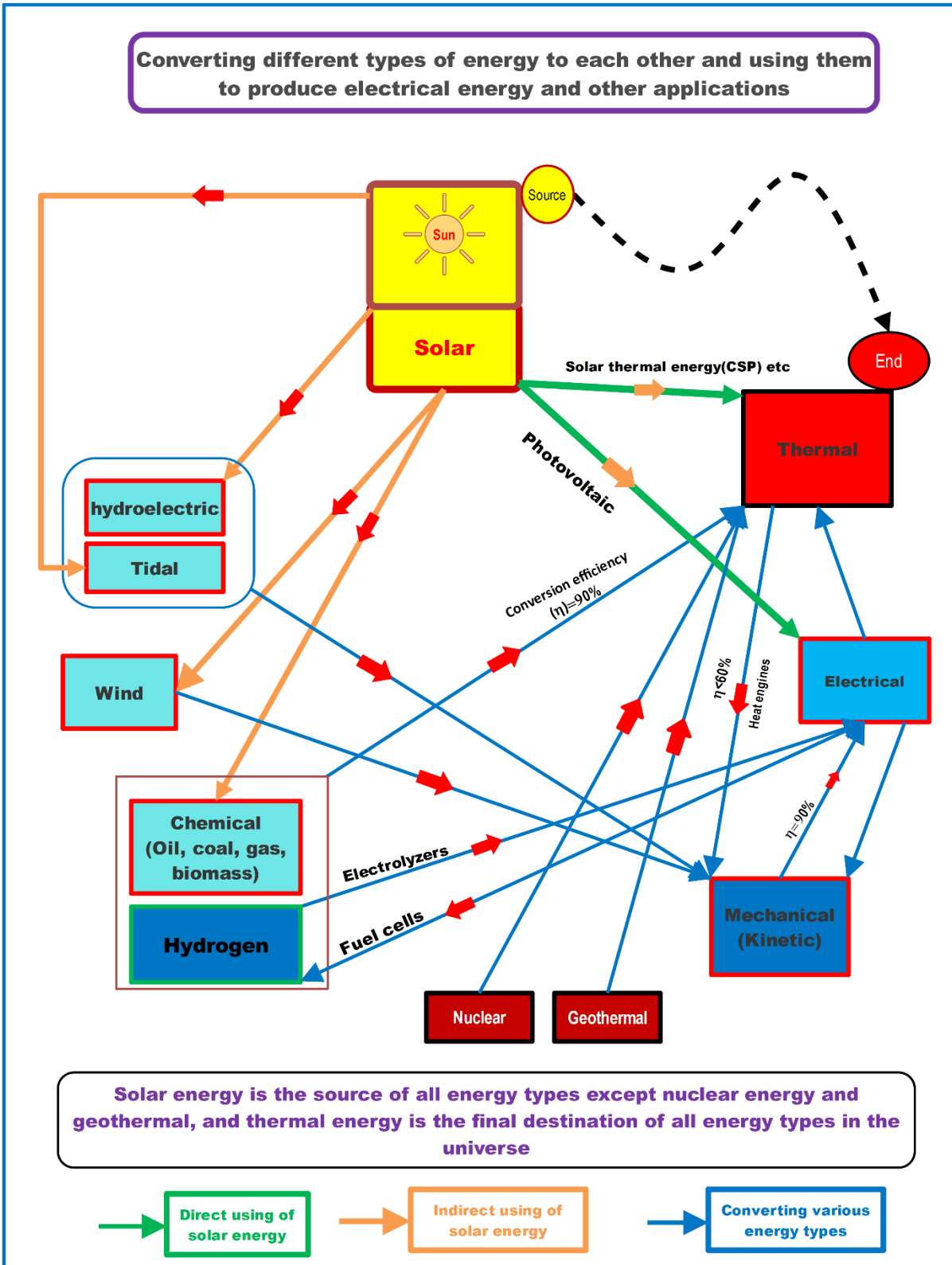


Figure 2: Converting different types of energy to each other and using them to produce electrical energy and other applications (one of the main goals of



*energy conversion on a large scale is to produce electricity, but it is not always the main goal)*

Chemical energy can be directly converted into electricity using a fuel cell. The most common fuel used in fuel cell technology is hydrogen. The energy conversion efficiency of fuel cells is almost 60%. A regenerative fuel cell can work in both directions and even convert electrical energy into chemical energy, which is called electrolysis. Typical conversion efficiency of hydrogen electrolyzers is reported to be 50-80%.

In nuclear power plants, energy is released as heat during nuclear fission reactions. Water vapor is produced with the help of heat obtained from nuclear fission. The continuation of the process of producing electricity from this water vapor is similar to other electrical energy production cycles, the Rankine cycle. Next, with the help of the produced steam, a steam turbine and then an electric generator moves, like most fossil fuel power plants, which supplies the required electricity.

## Electricity

Figure 3 shows the share of energy consumption in different years. In 2020, 20.5% of the world's total secondary energy is used as electricity, and this share is still increasing. Figure 3 also shows how electricity is supplied. Electricity is a form of energy that can be easily, cheaply, and with relatively small losses transmitted through the national power grid and is very clean. The transfer and use of this type of energy is easier and safer even compared to other energies such as natural gas. By using mechanical devices, electrical energy can be converted into mechanical energy, thermal energy and chemical energy and vice versa. This ability to convert into different types of energy has made electricity a widely usable form of energy. Electricity plays an essential role in many aspects of our lives, including lighting, heating, communication systems, electronics, industries, electric transportation, medicine, and many others. This wide range of applications has made electricity a very important source of energy in daily life and industry, and it is increasing day by day. It is important to understand that modern society as we know it would not be possible without electricity. Electricity has been in practical use for over 100 years now, and access to electricity greatly determines our standard of living.

According to the latest data available from the International Energy Agency, by 2021, approximately 759 million people worldwide did not have access to



electricity. This figure shows a significant decrease compared to previous years and progress in expanding the world's access to electricity. Approximately 1.7 billion people worldwide did not have access to electricity in 2000. In 2021, about 61% of electricity will be generated using fossil fuels, with coal as the main contributor. Because coal emits about twice as much carbon dioxide per kilowatt-hour produced as natural gas, coal-fired power plants are a major contributor to global warming. Nuclear energy accounts for 8.9% of the world's electricity production, and hydroelectricity has the largest share among renewable energy sources with 15%. Of the total electricity produced, about 40% of electrical energy is used for residential purposes and 47% in industry, and 13% of energy is lost in transmission. In recent years, transportation did not play an important role in electricity consumption, but it is expected that due to the importance of electric vehicles, their contribution will become significant. Figure 4 shows the share of electricity generation based on energy sources by year. It is noteworthy that the percentage of electricity production from among sustainable energies is growing only for solar energy and wind energy. Among all of them, the rate of growth of solar energy is the highest, and the share of production from hydropower, nuclear, and coal sources is always decreasing.

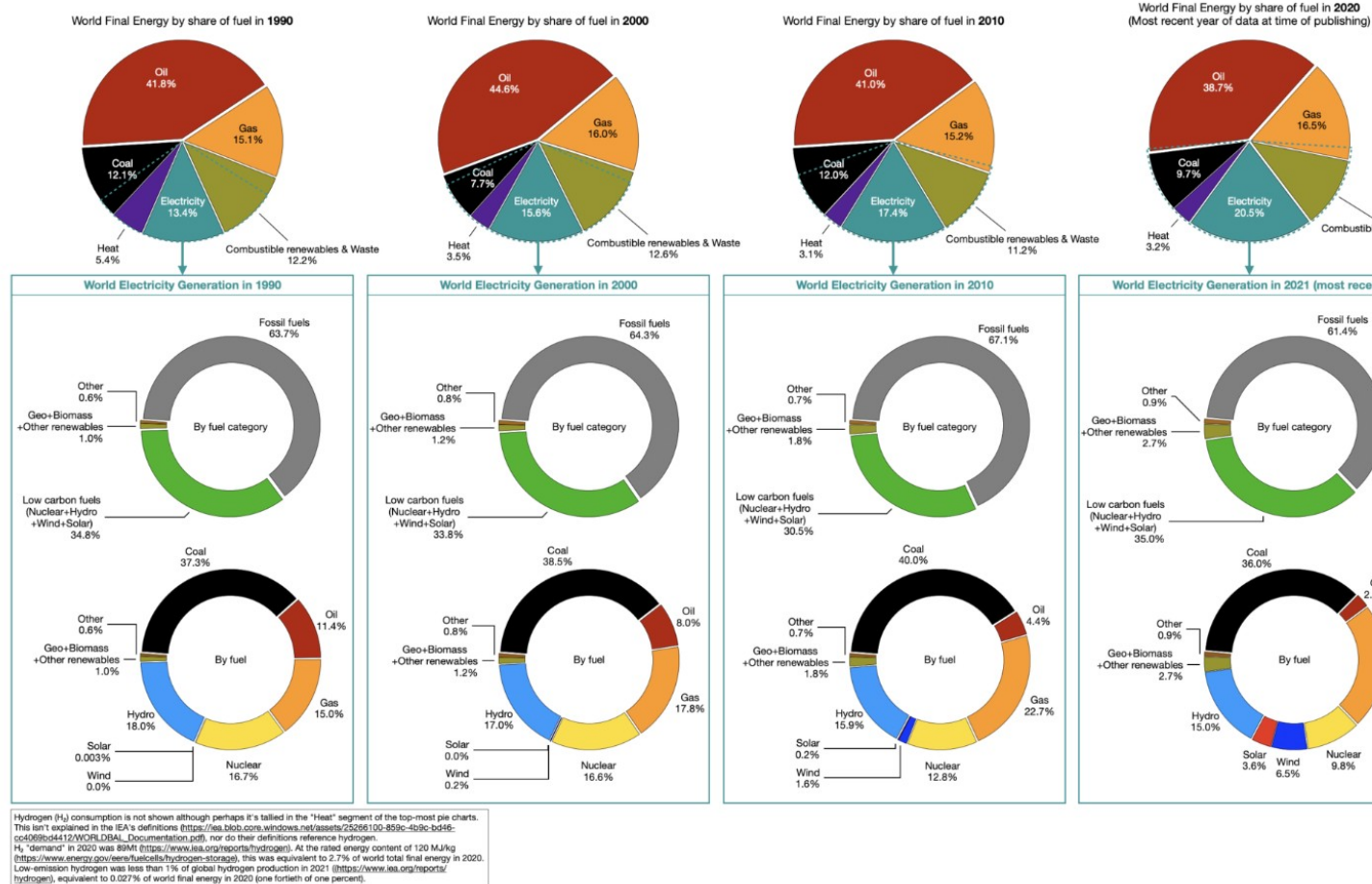
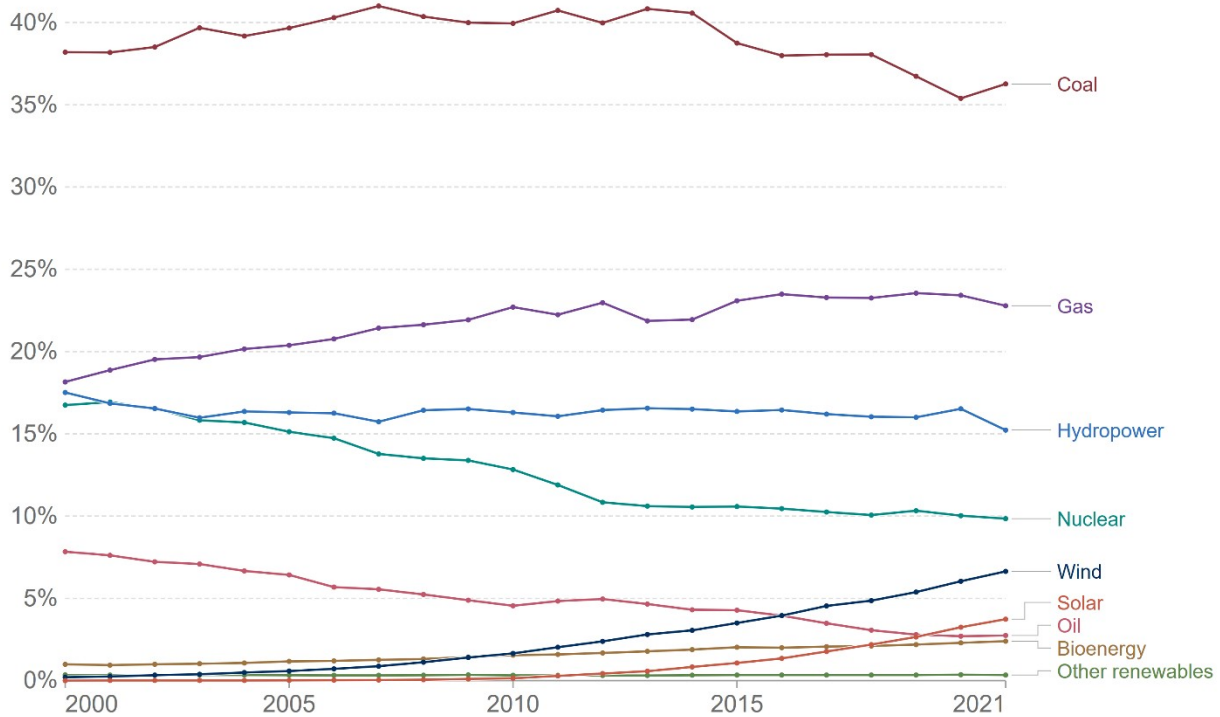


Figure 3: Energy consumption by energy services and energy carriers used to generate electricity for different years

## Share of electricity production by source, World

Our World  
in Data

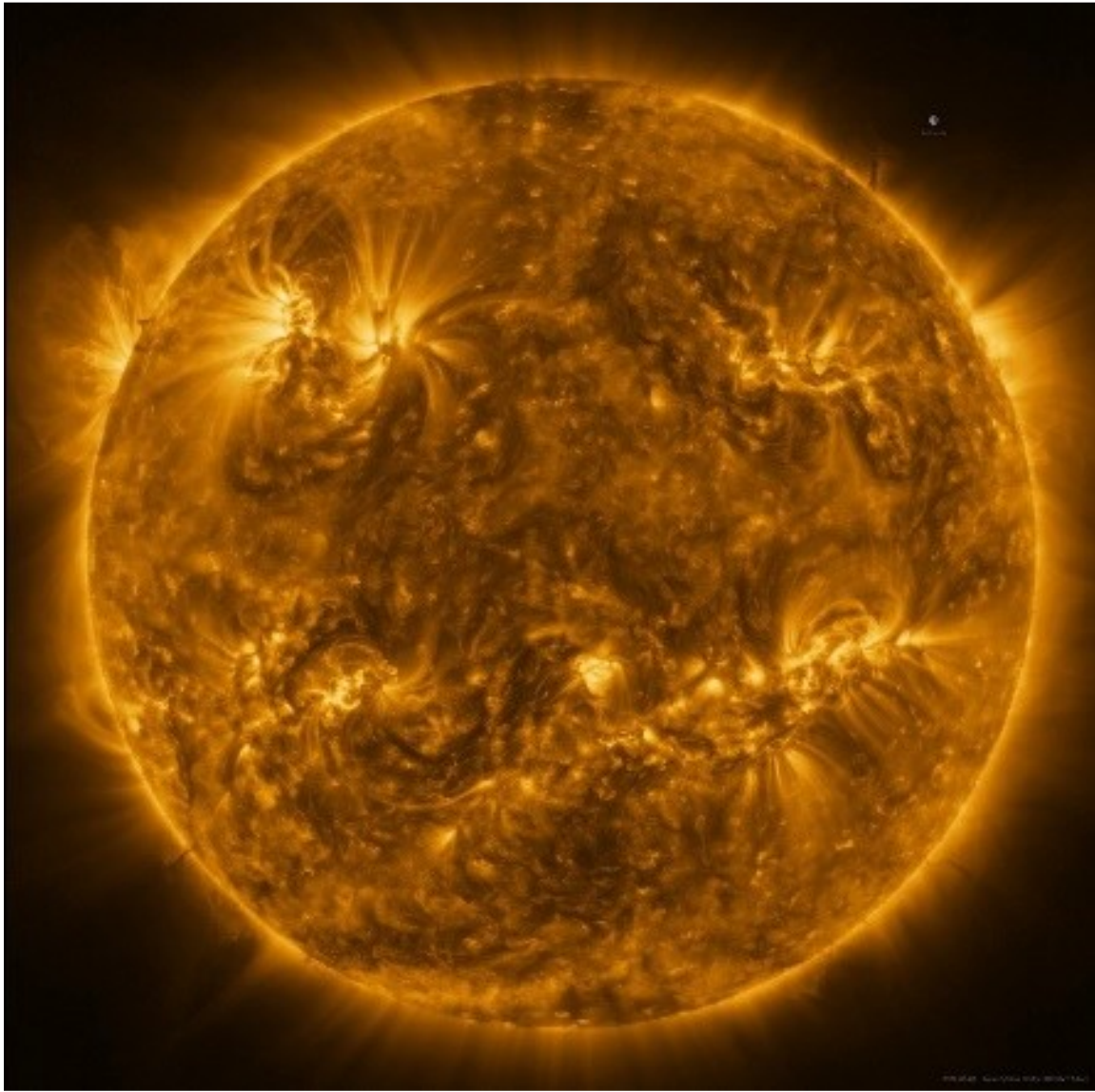


Source: Our World in Data based on BP Statistical Review of World Energy & Ember

OurWorldInData.org/energy • CC BY

Figure 4: Share of electricity generation based on energy sources

## The sun and solar energy



The closest image of the Sun star by the European probe on March 24, 2022 (this photo alone contains 99.86% of the total mass and volume of the solar system!)

*It seems that solar energy is a blessing for the purpose of increasing human survival and postponing its extinction, because the source of all energies (except nuclear and geothermal) is the sun, and we use their types indirectly and later (fuels). fossil and...) we use. Today, due to climate changes and the lack of fossil fuels, mankind seeks to develop technologies for the direct and immediate use of abundant and renewable solar energy much more than in the past. Omid Malai*

The sun star is the source and cause of all types of energy on earth except nuclear and geothermal energy. Even the reason for the generation of tidal energy is the effect of the sun and moon's gravity. The sun, which makes up 99.86% of the mass and volume of the solar system, seems to have a much more fundamental role than human imagination! A statistical study in recent years shows that the growth and importance of using solar energy is greater compared to other energies. What is the importance of the sun and solar energy for the solar system including the earth? Is it possible to provide all the inhabitants of the planet with the necessary energy to do their daily work in a cost-effective and pollution-free way? What is the role of solar energy in providing electricity to one billion people around the world who do not have access to electricity? What are the opportunities and obstacles? What is the impact of free, available and abundant solar energy on human life, fossil fuels, pollution and global warming and how will it be?



*Figure 5: A student studying with a candle in an area inaccessible to energy and electricity*



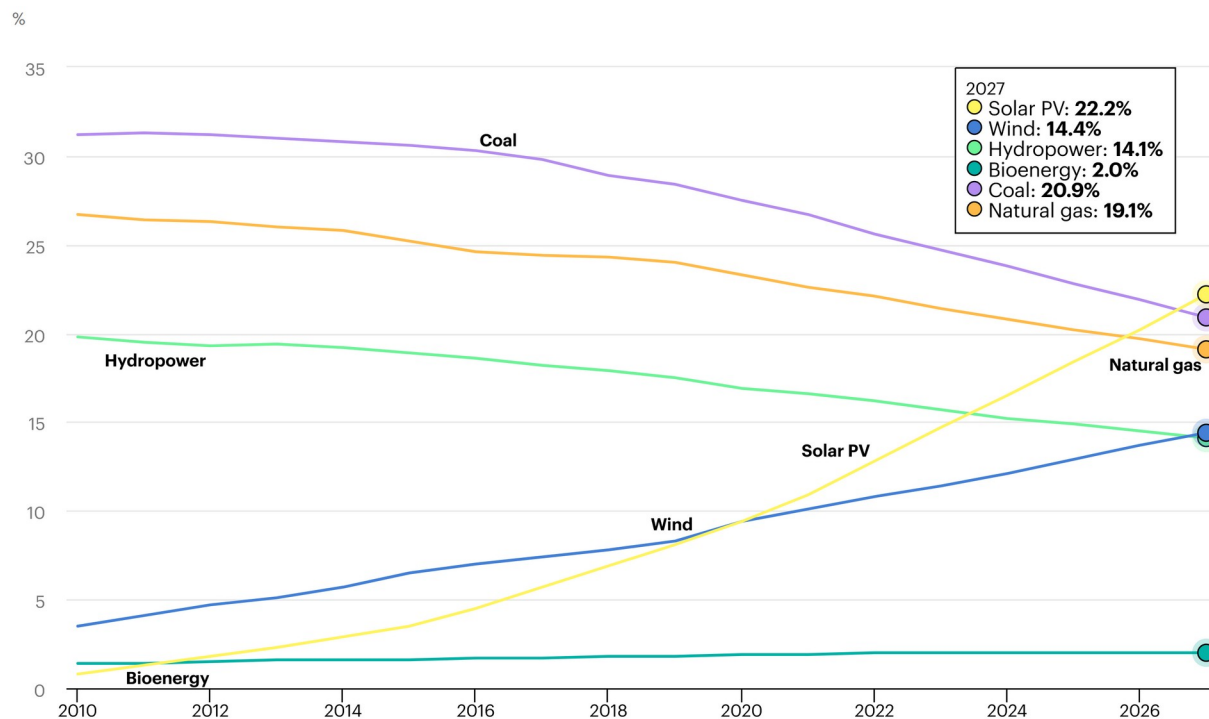


*Figure 6: Providing solar electricity in a virgin area in Africa*

The massive expansion of solar energy use worldwide by the middle of this century is likely to be an essential part of any serious approach and strategy to mitigate adverse climate change. Fortunately, the free and clean source of solar energy has the potential to supply a significant portion of future energy needs. The sun is an abundant and virtually inexhaustible source of energy that has greatly outstripped our current global energy needs and can supply our energy needs. In recent years, the cost of using solar energy has decreased significantly and its usage is growing rapidly. Today, solar energy accounts for only about 3.74% of the world's electricity production [6]. The use of non-renewable energy leads to the production of carbon dioxide. This production of carbon dioxide imposes a type of negative and destructive cost on the environment and humans. To compare the cost of using different energies, if the unfavorable cost of carbon dioxide production is considered, the use of renewable energies, especially solar energy, is completely economical [7]. If there is no penalty for carbon dioxide emissions, it will not be possible to increase the capacity of using solar energy to a high level. But if a significant change in government policies is implemented along with the climate challenge, the use of free, clean and inexhaustible solar energy will increase at a much faster rate. Unfavorable policies, intermittency, high cost and scalability are the most important obstacles and problems related to solar energy and other

renewable energies, which are discussed in detail below. Although the growth rate of the use of solar energy is higher than all other energies, these obstacles have still slowed down further progress in this field.

The International Energy Agency has predicted that solar energy will surpass all other sources from 2027 onwards. The agency has indicated that in 2027, 22.22 percent of energy will come from solar photovoltaics alone (even excluding other solar technologies). The diagram of this report is shown in Figure 7.

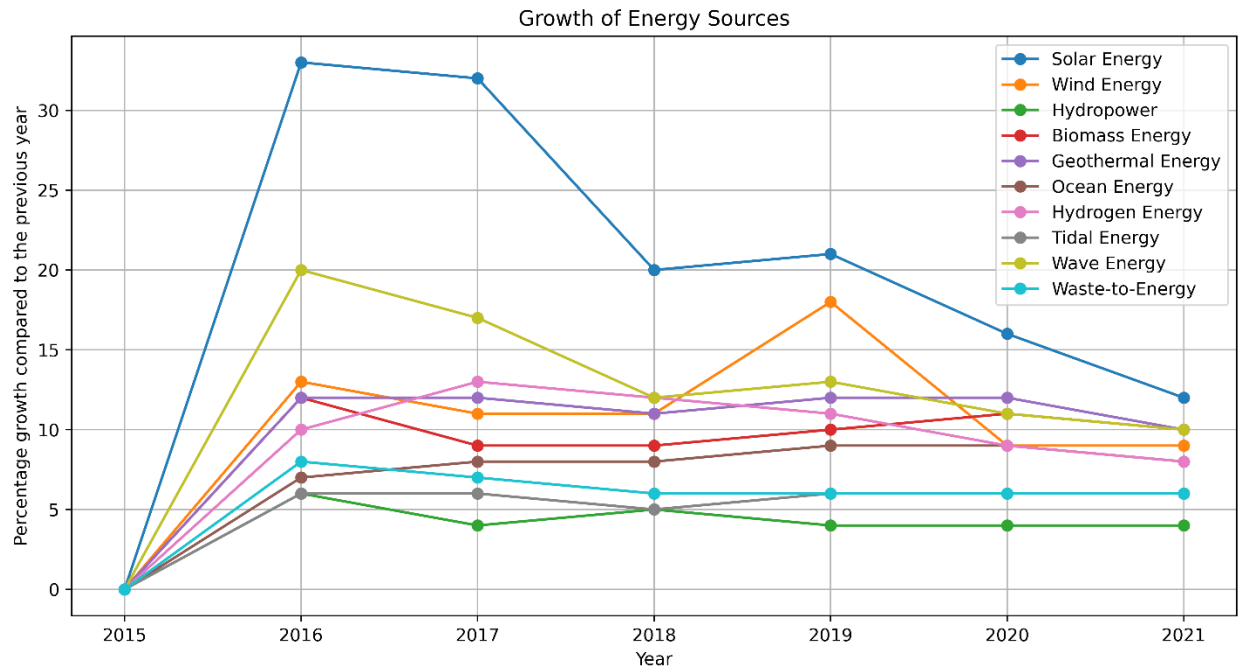


*Figure 7: Forecast of the share of energy resources until 2027 by the International Energy Agency (IEA)*

Figure 8 shows the comparison of the growth rate of renewable energy resources in different years based on percentage. It can be seen that the rate of growth of solar energy compared to other renewable energy sources is in the first place for all recent years. It is noteworthy that hydroelectric energy currently provides a large share of energy in the whole world, but the increase in its capacity is facing problems, and in the graph drawn, its growth rate is the lowest. In general, the use of renewable energy and natural gas has seen a high growth in recent years, oil has grown moderately, and the use of coal and nuclear power has decreased. The



reasons for these changes are the general movement of the global energy mix towards low-carbon and environment-friendly sources.



*Figure 8: Comparison of the percentage growth rate of energy resources in different years*

Solar power generation is one of the few low-carbon energy technologies that has the potential to grow on a very large scale. Consequently, massive expansion of global solar generation capacity to the multi-terawatt scale is likely to be a necessary and feasible strategy to mitigate the risk of adverse climate change. Recent years have seen rapid growth in installed solar generation capacity, major advances in technology, price and performance, and the development of creative business models that have encouraged investment in a variety of residential solar systems. However, further developments are needed to enable a significant increase in the share of solar energy at acceptable costs. Advances in these areas will help efforts to reduce greenhouse gases and develop electrical systems around the world. It also provides light, energy, power, well-being and comfort to more than one billion people around the world who now live without access to electricity. Solar energy can be converted into electricity, heat and chemical energy. The sun is the source of energy and responsible for almost all energy transfer processes that occur on Earth except for nuclear and geothermal energy. Wind is caused by the temperature difference between two areas of the environment, which is caused by the sun's radiation. Waves are created by wind and the gravity of the sun and moon, clouds and rain are formed by the evaporation of water by sunlight. Therefore, since the sun

is the only source of real energy, man must go to a period in which he directly uses solar energy to satisfy his energy needs.

In this chapter, the study of solar energy and various methods and systems of its use have been studied. Also, other energy sources such as fossil fuels and other renewable energies are mentioned as necessary, because the sun is their main source. Also, these concepts are necessary to understand the chain of conversion of different types of energy to each other and a comprehensive understanding of the field of energy. Advantages, disadvantages, obstacles and problems are discussed. The impact of this clean, free and renewable energy on human life has been discussed in terms of welfare, economy, environment and pollution, which leads to the correct use of solar energy in a practical way to meet needs. Also, the previous and future favorable and unfavorable policies of the policymakers were discussed and suggestions were made in this regard, which can be a good reference for the decision makers. In this chapter, in the order of basics related to solar energy and how it works, overview and overview of solar energy, review of some technologies of its use such as photovoltaic systems and centralized thermal power plants, various applications of solar energy, development and combination of systems Solar is explained with other energy sources and marketing. Finally, the summary of the presented materials has been examined in the form of a final approach.

## The sun and solar radiation

The sun is the star at the center of our solar system. The star is a giant glowing ball of hot gas, composed mostly of hydrogen (about 70 percent) and helium (about 28 percent). The diameter of the Sun is about 1.4 million kilometers, which is about 109 times the diameter of the Earth, and its mass is about 330,000 times that of the Earth. The Sun plays a vital role in sustaining life on Earth, providing heat and light that are essential for various biological processes and the planet's overall climate. The mass of the sun is so high that it constitutes 99.86% of the total mass and volume of the solar system. The mass of the Earth is only 0.17% of the mass of this system. Its structure is depicted in Figure 9 and some of its features are mentioned in Table 1.

The surface of the Sun is covered with dark spots called sunspots, which are regions of intense magnetic activity. Above the photosphere (the outermost layer of the sun), the sun's atmosphere is located, which consists of several layers. The first layer of the sun's atmosphere is the chromosphere, followed by the transition zone and then the outermost layer called the corona. The temperature in the chromosphere (the first layer of the Sun's atmosphere) starts at about 4,500 degrees Celsius (8,132 degrees Fahrenheit) and increases with altitude, rising to millions of degrees Celsius in the transition zone. . The Sun's corona extends to millions of kilometers in space and during a total solar eclipse, it is visible from the Earth as a weak and pearly white halo. The sun also emits a steady stream of charged particles called the solar wind, which spreads throughout the solar system. Occasionally, the Sun emits massive bursts of plasma and magnetic fields known as solar flares and coronal mass ejections. These can affect Earth's space weather and cause geomagnetic storms.

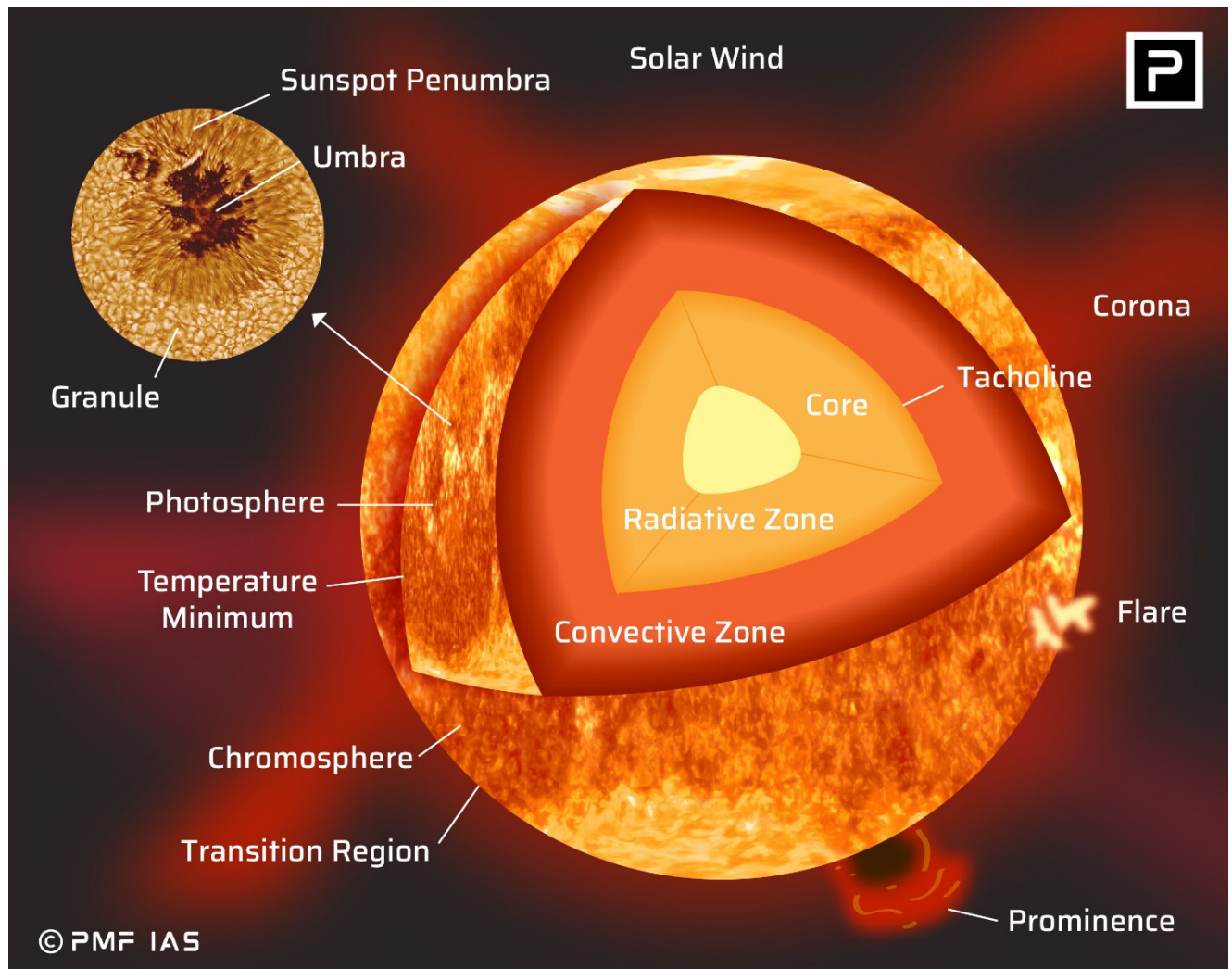


Figure 9: The structure of the Sun

Table 1: Some characteristics of the Sun

Age	4.6 billion years
surface gravity	<b>274 m/s<sup>2</sup> (28 times</b> the gravity of the Earth)
Speed of rotation	<b>7179.73 km/h</b> (earth's rotational velocity is <b>1675Km/h</b> )
Period of rotation	<b>25 days 9 h</b>
Rotation	<b>counter clockwise</b> (when viewed from a long way above Earth's north pole)

Composition	<b>98% of the sun is hydrogen &amp; helium</b>
Mean distance from the Earth	149600000 <i>km</i> (the astronomic unit, AU)
Diameter	1392000 <i>km</i> (109 × that of the Earth)
Volume	1300000 × that of the Earth
Mass	$1.99 \times 10^{27} \text{ kg}$ (332000 times that of the Earth)
Density (at the center)	$10^5 \text{ kg m}^{-3}$ (over 100 times that of water)
Density (at the surface)	<b>1410 <math>\text{kg m}^{-3}</math> (1.41 times that of water)</b>
Pressure (at the center)	over 1 billion atmospheres
Temperature (at the center)	about 15000000 °C
Temperature (at the surface)	5500 °C
Energy radiation	$3.8 \times 10^{26} \text{ W}$
The Earth receives	$1.7 \times 10^{18} \text{ W}$

The sun's energy is produced through a process called nuclear fusion, in which hydrogen atoms combine to form helium, releasing large amounts of energy in the form of light and heat in the process. The process of nuclear fusion also occurs in other stars. It means that the fuel used by the sun is hydrogen. If the solar fuel runs out, life in the solar system will definitely come to an end. But it takes billions of years to run out of all the sun's fuel, that's why solar energy is called a renewable energy. The fusion process requires very high temperature and pressure, which is very much available inside the Sun. The temperature of this star is estimated to be about 15 million degrees Celsius (27 million degrees Fahrenheit) and due to the massive mass of the Sun, the pressure inside is very high. The Sun's core is so dense that radiation cannot travel freely, but is constantly absorbed and reflected, so that it takes 10,000 to 170,000 years for the radiation to reach the Sun's surface!

During nuclear fusion in the Sun, mass is converted into energy according to Einstein's famous theory of special relativity. Although a small amount of mass is converted into energy in every nuclear fusion, according to this famous theory, the energy released is very large even for a very small mass<sup>2</sup>. For example, 167 grams of a substance is equivalent to 11.4 billion

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<sup>2</sup> In the Sun's core, hydrogen nuclei (protons) undergo a series of fusion reactions to form helium nuclei. The most common fusion reaction in the Sun is the proton-proton chain reaction, which consists of several steps. In the first step, two protons combine to form a deuterium nucleus (a proton and a neutron) with the release of a positron (a positively charged electron, the antiparticle of the electron) and a neutrino. This reaction can be shown as follows:

kilowatts of energy. This energy is the electricity needed for a big country like America with 340 million people (in August 2023) for one year! Although the process of converting nuclear energy is difficult and sensitive and this is not easily possible. Figure 10 shows a schematic of the nuclear fusion process in the Sun.

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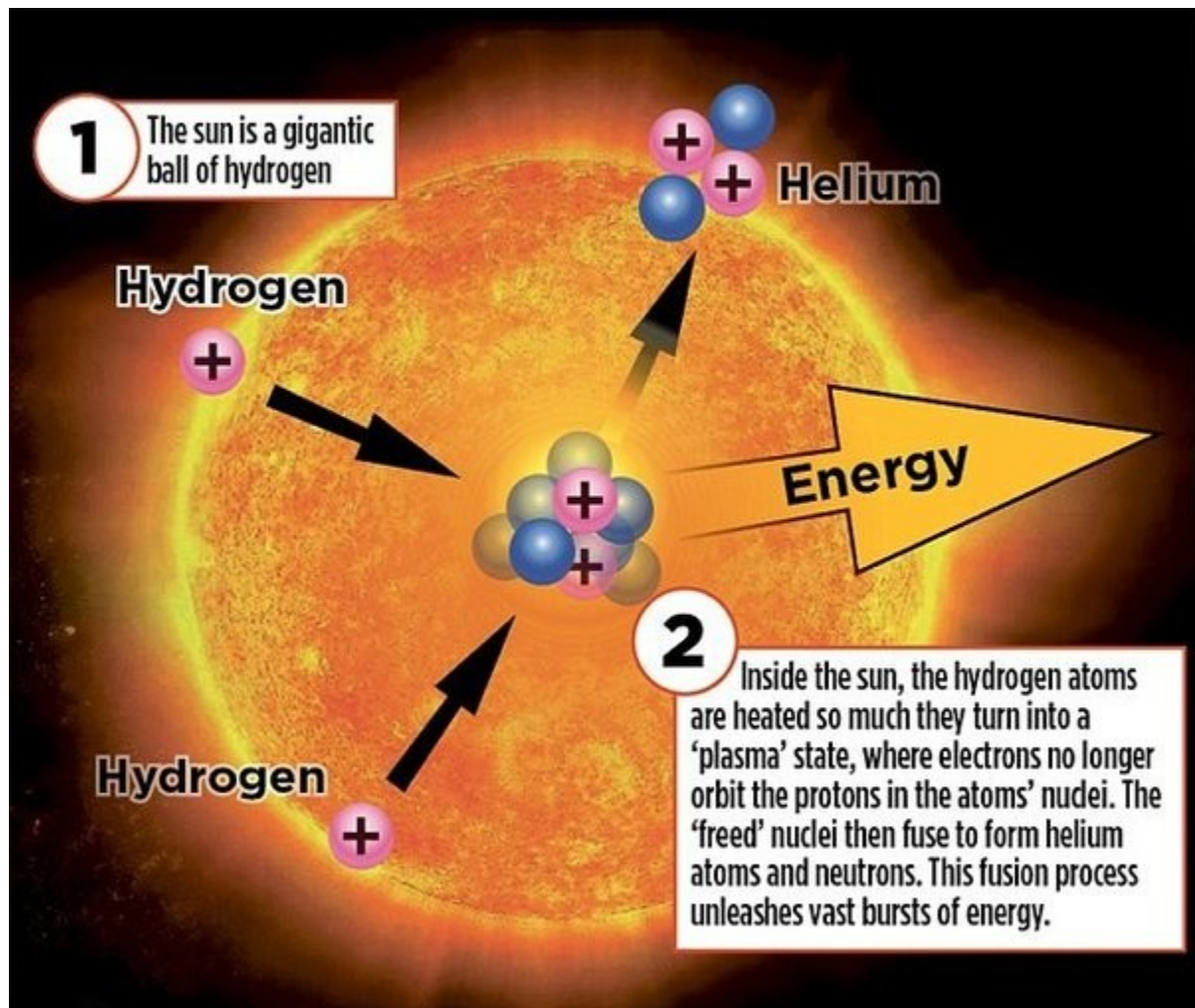
(Proton + Proton  $\rightarrow$  Deuterium + Positron + Neutrino)

The mass of two protons (primary particles) is slightly more than the mass of deuterium nucleus, positron and neutrino (final particles). This mass difference is converted into energy according to Einstein's equation. The next steps in the proton-proton chain reaction involve the fusion of more deuterium nuclei to produce helium nuclei. At each stage, some mass is converted into energy. The general reaction can be summarized as follows:

(4Protons  $\rightarrow$  Helium + 2 Positrons + 2 Neutrinos + Energy)

During the fusion process, a small fraction of the initial mass is converted into energy. Positrons annihilate with electrons, resulting in additional radiation. The mass of the helium nucleus is 0.635% less than the mass of four protons, and this mass difference is converted into energy according to Einstein's equation. This energy is radiated as light and heat and provides the brightness and warmth of the sun.





*Figure 10: Nuclear fusion inside the sun [10]; Hydrogen atoms are converted into helium, during this process some of the initial mass is converted into energy and is released as light and heat (electromagnetic waves)*

Every second, approximately 4 million tons of mass are converted into energy in the Sun. Based on that, the power density in the center of the sun is estimated to be about 275 watts per cubic meter with theoretical assumptions. It seems like the amount of mass that the sun loses every second is huge, but the total mass loss is very small compared to the total mass of the sun. The Sun maintains its mass and energy balance through the continuous conversion of hydrogen into helium in its core.

Neutrinos are produced in the nuclear process in the sun. Neutrinos are very small particles with no electrical charge and are ejected from the Sun almost immediately after being produced. They are highly permeable both in vacuum and in matter and have almost no interaction with matter along



the way. Neutrinos in the Sun hardly interact with matter and therefore can leave the Sun's core unhindered. Every second, about  $6.5 \times 10^{10}$  neutrinos pass through the earth per square centimeter, and as a result, they also pass through our bodies. Neutrinos make up about 2% of the total energy radiated by the Sun. The rest of the radiation is released as electromagnetic radiation.

The outermost layer of the sun is called the photosphere, which we see as the surface of the sun. This part behaves like a black body and is the source of solar radiation that hits the Earth. A blackbody is an ideal physical object that absorbs all incoming electromagnetic radiation without reflection or transmission. While the Sun shares several properties with a black body, it does not fit the ideal model perfectly. Real-world factors such as the Sun's constituents, magnetic fields, and atmospheric effects influence the behavior and spectral properties of the Sun. Because of this, its temperature appears yellow, and its average surface temperature is about 5,500 °C (9,932 °F). The solar constant is the total power density of solar radiation at the average distance between the earth and the sun in a plane perpendicular to the direction of the sun, which is approximately 1361 W/m<sup>2</sup>.

Stefan Boltzmann's law<sup>3</sup> states that as the temperature of the black body increases, more energy is emitted exponentially and with the fourth power per unit area. That is, the higher the temperature of an object, the greater the intensity of the corresponding radiation and increases to the fourth power. This relationship is essential for understanding various phenomena related to thermal radiation, such as the energy output of stars, heating of bodies, and temperature distribution of planets. It is worth noting that while Stefan Boltzmann's law was derived for ideal black bodies, it provides an accurate description of the behavior of real bodies that absorb and emit radiation.

Understanding the Sun's behavior and studying its various phenomena is crucial for space exploration, satellite communications, and the prediction of space atmospheric events that can affect technology and infrastructure on Earth. Scientists use telescopes, satellites, and other instruments to

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<sup>3</sup> One of the most useful and efficient laws about radiation is the Stefan-Boltzmann law. Named after physicists Joseph Stefan and Ludwig Boltzmann, this law relates the total energy radiated by a perfect blackbody to its temperature. This law states that the total radiant power emitted per unit area of a black body is directly proportional to the fourth power of its absolute temperature. Mathematically, it can be expressed as follows:

$$P = \sigma A T^4$$

where P represents the radiant power or the total energy emitted per unit time, A is the surface of the black body, T is the temperature of the black body in Kelvin, and  $\sigma$  is the Stefan-Boltzmann constant. This law shows that as the temperature of the black body increases, more energy is emitted exponentially and with the fourth power per unit area.

observe and analyze the Sun's activity, providing valuable insights into the physics of stars and the nature of our universe. Scientists on Earth are also actively working on the development of controlled nuclear fusion as a potentially clean and nearly unlimited source of energy. However, replicating the conditions of the Sun's core in a controlled manner is an important scientific and engineering challenge that has yet to be fully overcome.

## Solar Energy

One of the carriers of renewable energy is solar energy. Solar energy technology converts sunlight into electricity by using photovoltaic cells and concentrated solar power. These methods are explained in the following sections. The technology has become increasingly affordable in recent years, making it an attractive option for homeowners and businesses seeking independence from fossil fuels. If sunlight is directly converted into electricity using devices based on semiconductor materials, it is called photovoltaic. Typical efficiency of solar modules is in the range of 15-20%. Sunlight can also be converted into heat, which is called solar thermal energy or concentrated solar power. For example, water or another fluid can be heated by sunlight mediated by a black absorbing material. This hot fluid can be used for heating buildings or even cooling. From concentrated solar energy systems, a fluid with a temperature of several hundred degrees is obtained, which is used to generate steam and thereby drive a steam turbine, followed by a generator, to produce electricity. In addition to producing heat and electricity, solar energy can also be converted into chemical energy. This technology is called solar fuel. To produce solar fuels, photovoltaics and regenerative fuel cells can be combined. In addition, sunlight can also be directly converted into fuel using photoelectrochemical devices. In the following, photovoltaic modules and concentrated solar power are discussed in detail.

Solar energy is a renewable and abundant source of energy that comes from the sun's rays. As a clean energy solution to combat climate change and reduce dependence on fossil fuels, it is increasingly attractive. There are various technologies for using solar energy, which are discussed in the following sections.

Today, solar energy has a relatively small share of electricity generation in the world. In 2021, this share is about 3.74% of global electricity production. But the growth rate of this share is very important compared to other sources of electricity production, and with this growth rate, it is predicted that this energy will play a very important role in the global energy system by the middle of the century. As several important barriers to solar energy are removed over the next few decades, the likelihood that this energy will be able to meet critical needs will increase dramatically. The aim of this study is to set up appropriate solar systems, to help decision makers about solar energy in the future, to identify barriers that may prevent solar technologies from achieving this potential, and to identify appropriate public policies that can mitigate current barriers and problems.

The increasing importance of solar energy is due to the depletion and scarcity of fossil fuels in the future and the deep long-term threat of global climate change. The emission of carbon dioxide caused by the combustion of fossil fuels causes climate change and global warming. Carbon dioxide is the largest share of greenhouse gases in the atmosphere, which has been increasing at an ever-increasing rate since the industrial revolution. Almost two-thirds of carbon dioxide emissions from fossil fuels are related to electricity generation, heating and transportation. In order to reduce the problems related to climatic and environmental changes, the ratio of

carbon dioxide emissions to global energy consumption should be reduced significantly and in proportion to global economic growth.

Solar energy has the potential to play an important role in the future of meeting energy needs. The technology of using solar energy to produce electricity with very low carbon dioxide emissions has been developed to an acceptable level, and the use of electricity for industry, transportation, heating, etc. has already become clear. In addition, the solar energy source is very abundant, which can supply a large part of the world's energy consumption and exceeds the potential of other renewable energy sources. We will discuss this further. Of course, it should be noted that some greenhouse gases are produced during the installation, maintenance and decommissioning of solar energy systems, but their amount is much less than the emission of harmful gases related to fossil fuels. An effective way to reduce carbon dioxide emissions at the same time as the growth of energy consumption will be a significant increase in the use of renewable energy, especially solar energy, for electricity generation, transportation, heating, cooling and other applications.

The International Energy Agency has recently proposed different approaches for the global response to the risks of climate change. The plan is to reduce carbon dioxide emissions during energy conversion in 2050 to less than half of their 2011 levels. The International Energy Agency predicts that emission reductions will be realized at a lower cost, and one of the scenarios considered is that the growth of nuclear power is limited by non-economic factors. The agency predicts that global demand for electricity will increase by 79 percent between 2011 and 2050. Wind, hydro, and solar power will account for 66 percent of global electricity generation in 2050, and solar power alone will provide 27 percent of the world's electricity. It is likely that in the future, the increasing use of hydropower systems will be limited for environmental reasons, in which case solar energy should play a greater role in providing global electricity so that less carbon dioxide is emitted. Today, there are environmental problems in the development of hydropower facilities in many countries of the world, and it is predicted that these problems will become more acute in the future.

In the following, we discuss three obstacles to the progress of solar systems, which are: cost, scalability, and intermittency. Firstly, the cost of solar electricity has decreased drastically in recent years and it can be expected that it will decrease even more in the future. Now, in many countries, the use of solar energy for electricity generation is still more expensive than the use of fossil fuel power generation systems.

In addition, solar energy is artificially cost disadvantageous, since fossil energy users do not pay any damages for the emission of carbon dioxide and other gases produced. Applying such a scenario and comprehensive policies for users can greatly reduce the emission of harmful greenhouse gases. If the use of solar energy increases, the average cost of solar electricity will decrease, because the cost of supplying this solar energy will decrease during the sunny hours and especially the peak hours of solar radiation when the most solar energy is produced. This means that even where solar generation is more expensive than or equal to fossil energy

generation, its cost must be reduced significantly to be cost-effective at higher levels of use.

Second, if solar energy becomes the main source of electricity production by the middle of this century, solar technology, industry and its supply chain will have to develop greatly. In the scenario of the International Energy Agency, the amount of solar electricity production will increase to more than 50 times the amount of 2013 by 2050. Of course, the development of some solar technologies has problems due to rare materials. Scaling up production to this magnitude is likely to be economically difficult. Based on what has been observed so far, the limitations of materials like silicon are probably not a serious threat to the emerging solar energy industry.

Third, solar energy is intermittent and unstable: one of the characteristics of solar radiation is its unpredictability and intermittency. This feature is one of the major obstacles to using solar energy on a large scale and being unreliable. It is important to match the amount of production and demand for power systems. In addition to the fact that production fluctuations are unpredictable, demand fluctuations are also completely unpredictable. Small-scale solar energy production does not pose a big problem. But in a power system that is heavily dependent on solar energy, the intermittency of the solar source makes the net load (the amount of electrical energy that must be supplied by the energy sources) more variable and less predictable. On a smaller scale, according to the IEA scenario, most systems can overcome the intermittency of solar energy and the variability of production and demand loads by using more flexible fossil fuel generators. However, in most energy systems, especially if solar energy is used on a significant scale, the development of large-scale energy storage technologies is needed.

By any standard, the solar energy source is enormous. Today, a very small percentage of the world's land area is used for solar power plants. For example, in the United States of America, at least one-third of the country's area is used to produce corn, from which ethanol is produced. It provides only 7% of the country's energy for gasoline production. Whereas, if only 0.4% of the country's area is allocated for solar power plants and these power plants receive half of the annual solar radiation capacity, the entire country's energy will be supplied for one year. The area of use for solar power plants in America in 2021 is 0.027% (1034 square miles of 3.8 million square miles are dedicated to solar power plants).

On a global scale, solar resources are widely distributed in addition to being abundant. Wherever there are people, sunlight is available.

Figure 11 shows a map of the distribution of solar energy sources on the planet. Also, the histograms of land area, population and average solar radiation are shown as a function of latitude and longitude. It is noteworthy that according to the map and images provided, none of the other resources such as fossil fuel and good locations for wind or hydroelectric power generation are distributed as well.

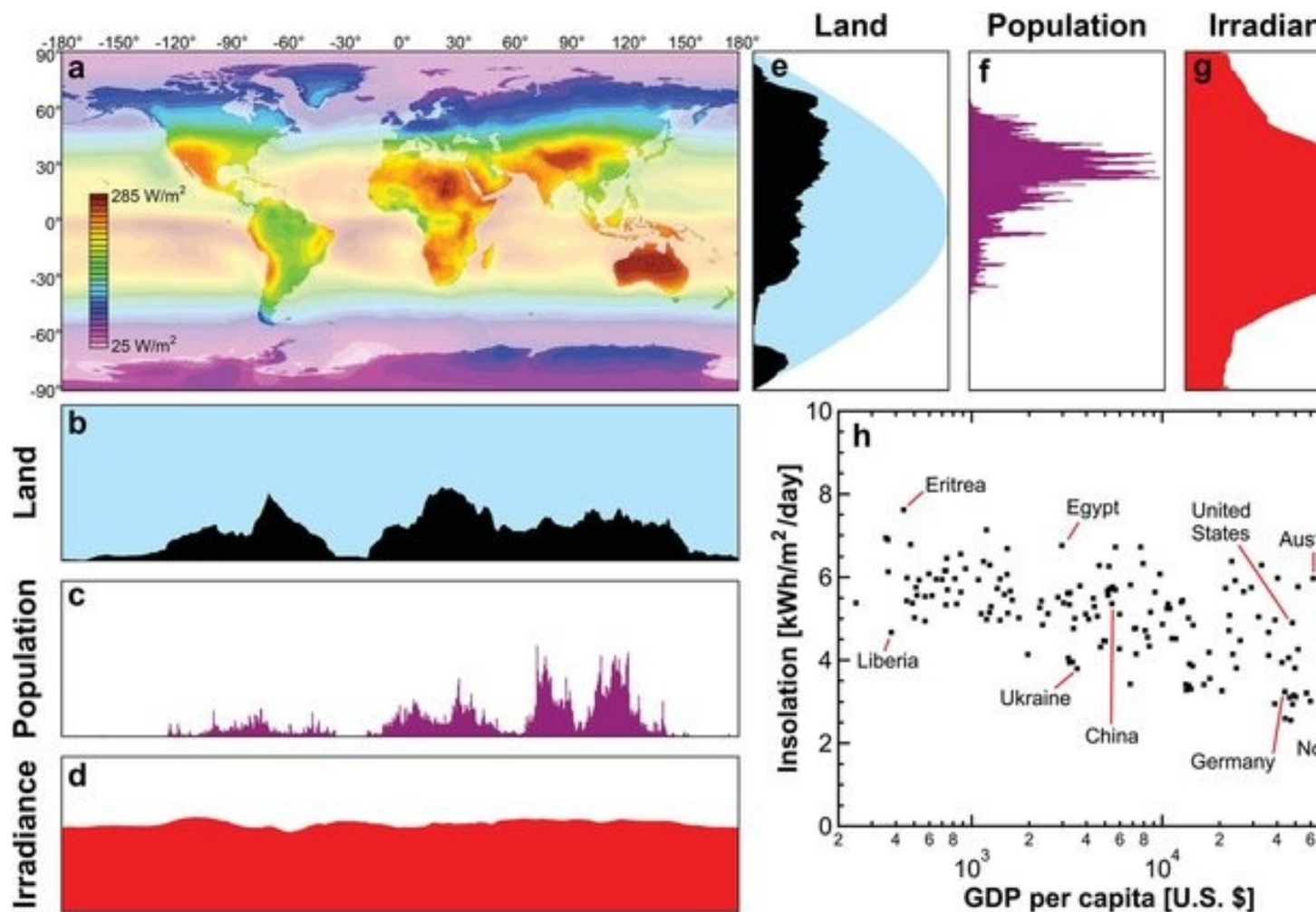


Figure 11: Distribution of solar energy sources in the world

Figure 11 - a) shows the average intensity of solar radiation for different parts of the globe. Figure b) the amount of land area (black areas of land and blue areas show oceans) Figure c) Population and Figure d) shows the average solar radiation along the longitude. Figures e to g show these along latitude. Figure h shows the relationship between average radiation and GDP per capita<sup>4</sup> for countries around

<sup>4</sup> Gross Domestic Product (GDP) is a measure of the total value of goods and services produced within the borders of a country in a specific period of time (usually a year). It includes the value of goods and services produced by domestic and foreign entities within the country's borders. In the field of solar energy, GDP

the world for 2011. The range of changes in GDP is more than the range of changes in the average intensity of solar radiation, and countries with low economic status have good access to solar energy. It can also be seen that the intensity of solar radiation is higher in the areas of the earth where the population is high. In the southwestern United States of America, in the continent of Europe and South Asia, and in the continents of Australia and Africa, almost all areas are suitable places for solar power plants due to more solar radiation.

## Solar energy technologies

In recent years, the necessity of transition to sustainable and environmentally friendly energy sources has been clearly revealed. One of the best ways to achieve these goals is to use solar energy in different ways. Technology and tools are needed to use solar energy. In general, there are five technologies for using solar energy. These five technologies are: photovoltaic systems (conventional and thin), concentrated solar energy or solar thermal energy, solar heating and cooling, solar fuels and passive solar design. In this section, the different types of solar energy technologies are explained, and photovoltaic systems and concentrated solar energy (or solar thermal energy) are examined in more detail. The different applications of solar energy for each of these technologies are mentioned in the following sections.

Figure 12 shows a picture of a photovoltaic power plant in China from a distance. Figure 13 shows the image of a concentrated solar power plant of the heliostat type.

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can be used to evaluate the economic impact of solar energy on a country. For example, installing and maintaining solar energy systems can create jobs and contribute to a country's GDP. In addition, the use of solar energy can lead to a reduction in dependence on fossil fuels, thereby helping to reduce a country's trade deficit and increase its GDP.





*Figure 12: A photovoltaic power plant in China*





*Figure 13: Heliostat concentrated solar power plant (CSP or solar thermal power plant)*

A solar thermal power plant is usually used on a large scale with a production capacity of, for example, 100 megawatts. This type of power plant can store the sun's thermal energy for hours with low sunlight and night and use the stored energy whenever needed.

Photovoltaic systems can be installed on both large and small scales. The small scale of these systems is, for example, residential photovoltaic installations on the roofs of residential buildings, whose power generation capacity is usually less than 10 kW [14]. Or, for example, a small photovoltaic panel that provides electrical energy for traffic signs in a remote area. The amount of electricity produced by these photovoltaic systems depends on changes in the intensity of the sun's radiation. A photovoltaic system can use all the sun's radiation and produce electricity, but a concentrated solar energy system uses only direct radiation. As a result, the solar radiation receiver of a concentrated solar energy system is more sensitive to the presence of clouds, fog and dust, but due to the ability to store thermal energy in it, its output is more stable than a photovoltaic system. As a result, for cloudy areas, a photovoltaic power plant is more economical than a solar thermal power plant because it requires less thermal energy storage devices.

## Photovoltaic systems

Photovoltaic systems are the most well-known solar energy technology. A photovoltaic cell, called a solar cell, directly converts sunlight into electricity. The word photovoltaic was mentioned for the first time around 1890 and comes from the Greek words photo, "phos" which means light and "volt" which refers to electricity. The first modern solar cells were produced in 1954 and installed on a US space satellite in 1958.

Figure 14 shows the schematic of the electricity production components from the photovoltaic panel to its consumption, and Figure 15 describes the schematic of the implementation of a photovoltaic system on the roof of a house. Photovoltaic panels convert a significant part of the sun's energy into electrical energy. These panels are designed to effectively absorb sunlight and convert it into low voltage direct current electricity that can be used by various household appliances and electrical devices. To ensure a continuous and stable power supply, a critical component in the system is the battery. The excess electricity produced by the photovoltaic panels during the peak hours of the sun charges the battery. The battery acts as an energy reservoir and stores excess electricity for later use when sunlight is not available or can sell it to the national grid when energy demand increases. Another vital component is the hybrid inverter that performs multiple functions. The inverter, which acts as the heart of the system, converts the DC electricity produced by the photovoltaic panels into alternating current electricity. Alternating current (AC) is the standard form used for most electrical appliances in homes, and almost all electricity is transmitted as alternating current (AC) in power transmission and distribution systems. When the PV system produces more electricity than the household needs, the excess power can be fed into the grid. This integration with the grid, controlled by the hybrid inverter, allows homeowners to benefit from grid metering or feed-in tariff programs. For example, during peak consumption hours when energy is expensive, sell this energy to the grid.

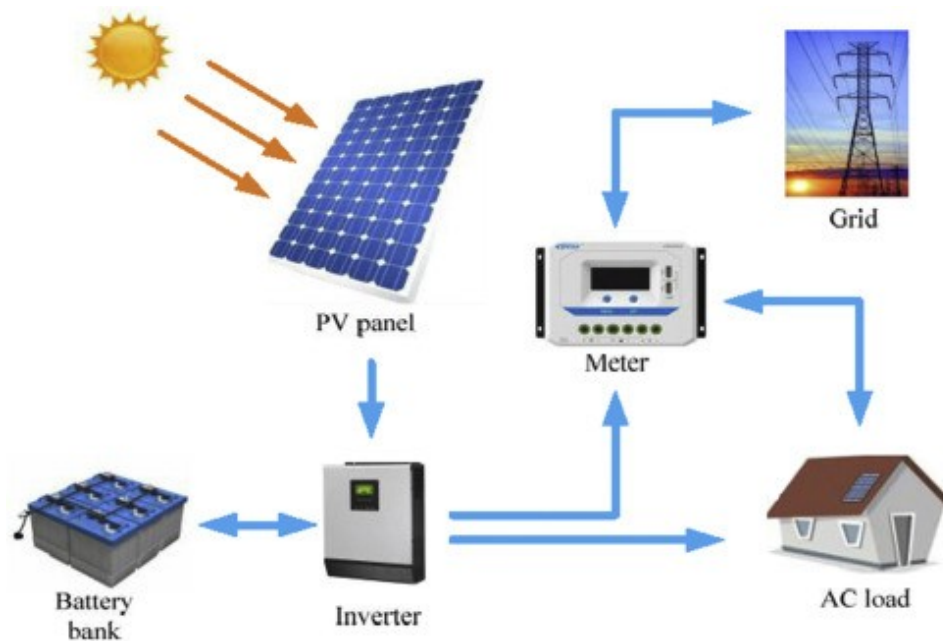


Figure 14: Schematic of electricity production components from a photovoltaic panel to consumption

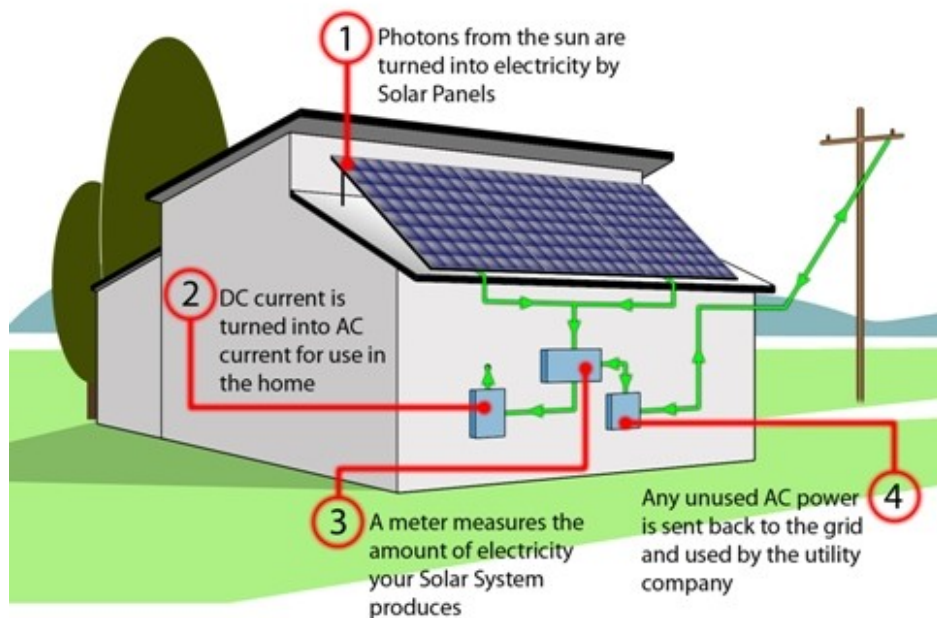
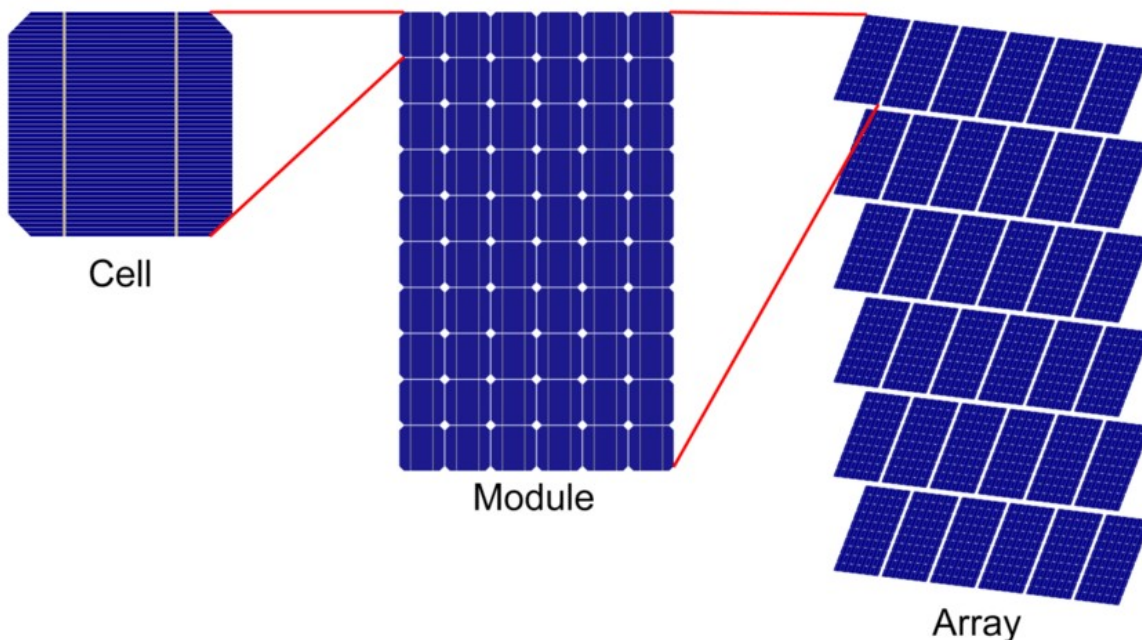


Figure 15: Schematic of the implementation of a photovoltaic system on a roof house



In summary, the sequence of electricity production in a photovoltaic system on the roof of a house or a large photovoltaic power plant includes converting solar energy into DC electricity through photovoltaic panels, storing excess energy in batteries for future use, converting to a hybrid DC power inverter. to AC. This process allows homeowners to generate their own clean energy, earn money from it, contribute to environmental sustainability, and move toward a greener future.

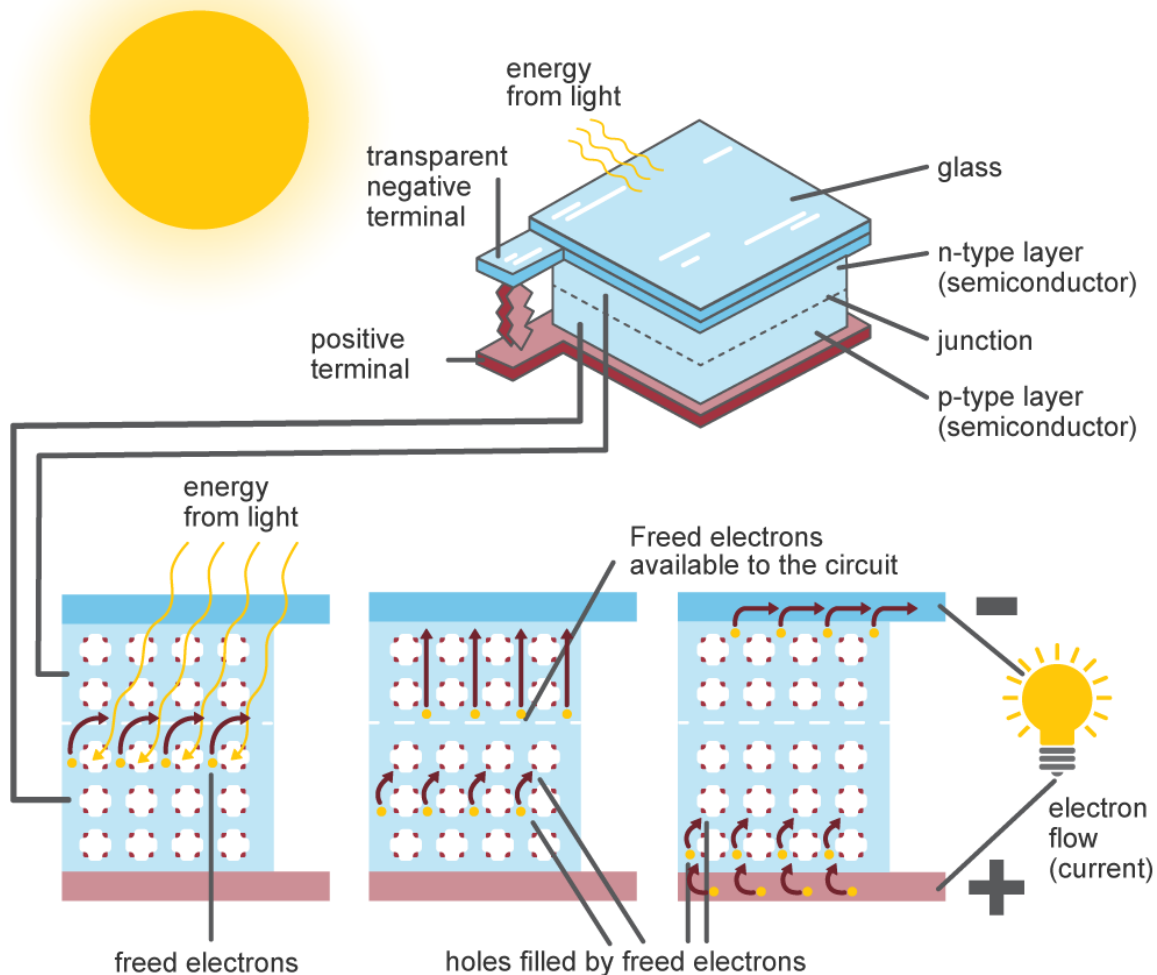
A photovoltaic cell is usually small (about a few centimeters) and produces about 1 or 2 watts of direct current power. These cells are made of different semi-conducting materials and often their thickness is less than four human hairs. Some photovoltaic cells can convert artificial light into electricity. The structure of a solar array is shown in Figure 16. A solar array, which is used to generate high power, consists of a number of modules. The module itself consists of a number of solar cells that can be connected in series and parallel. The efficiency of these modules is higher in the cold, i.e. winter season, than in the summer season, and over time, their efficiency decreases like batteries. The efficiency of these modules varies based on the manufacturing technology, but it is 20% on average.



*Figure 16: Cell, panel (module) and solar array*

Sunlight consists of photons or particles of solar energy. These photons contain different amounts of energy. When photons strike a photovoltaic cell, they may be reflected from the cell, pass through the cell, or be absorbed by the semiconductor material. Only absorbed photons provide energy to generate electricity. When semiconductor materials absorb enough sunlight, electrons are ejected from the material's atoms. The special behavior of the surface of the material during manufacturing makes the front surface of the cell receptive to displaced or free electrons so that the electrons migrate naturally to the cell surface. The materials used are designed to behave specifically so that electrons are naturally transported to the surface of the cell. The movement of electrons towards the front surface of the solar photovoltaic cell causes an imbalance in the electrical charge between the front and back surfaces of the cell. This imbalance creates a voltage potential like the negative and positive terminals of a battery. The electrical conductors on the cell absorb the electrons. When the conductors in an electrical circuit are connected to a battery or, for example, a light bulb, electricity flows through the circuit. Figure 17 shows the structure and function of a photovoltaic cell.

## Inside a photovoltaic cell



Source: U.S. Energy Information Administration

*Figure 17: Structure and function inside a photovoltaic cell*

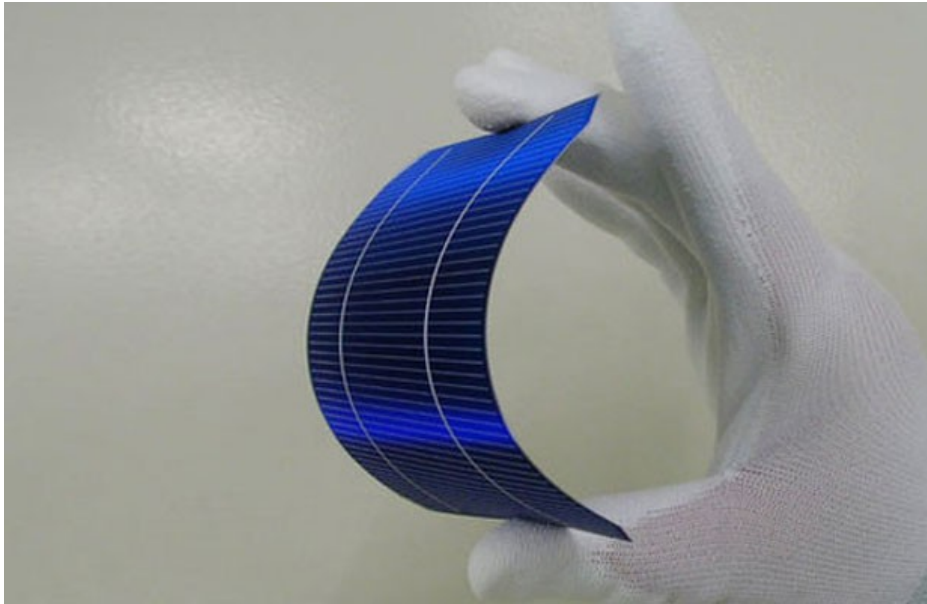
The production of photovoltaic cells in turn has different technologies, and as a result, each of them has its own specific applications. Some of the most important technologies for making these cells are summarized as follows:

**Mono-Si (Mono-Si):** This technology uses high-grade silicon with a monocrystalline structure, resulting in good efficiency and performance. Commonly used in residential and commercial applications.

**Polycrystalline Silicon (Poly-Si):** Polycrystalline cells are made of multiple silicon crystals, which reduces manufacturing costs. They are less

efficient than monocrystalline silicon, but are widely used because they are cheap.

**Thin-film solar cells:** Thin-film solar cells are made by placing a thin layer of semiconductor material on a substrate such as glass or metal. This technology offers flexibility, lightweight design and lower manufacturing costs. Materials such as amorphous silicon or cadmium telluride are used for construction.



*Figure 18: A flexible thin film photovoltaic cell*

**Concentrated Photovoltaic Systems:** These types of systems use lenses or mirrors to focus sunlight onto small, high-efficiency solar cells. By concentrating sunlight, these systems can achieve higher conversion efficiency than conventional photovoltaic systems.

**Double-sided solar panels:** Double-sided panels are designed to absorb sunlight from both sides and increase energy production because they can absorb direct sunlight from the front and reflected sunlight from the back. Double-sided panels can be used in a variety of applications such as solar boats and rooftop installations.

**Perovskite solar cells:** Perovskite solar cells are a type of thin film solar cell that uses a compound with a perovskite structure as a light harvesting layer. They have shown rapid improvements in productivity and offer a



potentially cost-effective and highly efficient solution. However, commercialization is still ongoing and more research is needed.

**Solar Tracking Systems:** Solar tracking systems adjust the position of solar panels to follow the path of the sun throughout the day and maximize energy production. Tracking systems can be uniaxial (following the sun's movement from east to west) or biaxial (following the movement east-west and up-down).

**Photovoltaic combined with building:** refers to the integration of solar panels in building materials such as roofs, windows and facades. This technology enables the seamless integration of solar power generation into building design, offering both functional and aesthetic benefits.



*Figure 19: An integration of building materials with photovoltaic cells*

Photovoltaic installation cost is usually divided into two parts: the cost of the solar module and the so-called system balance costs, which include the costs of converters, hardware installation racking, design work and installation costs, marketing as well as monitoring costs and Financing is different. Photovoltaic technology choices affect module costs and system balance. After decades of development, supported by significant research and development investments, today's leading photovoltaic solar technology, wafer-based crystalline silicon<sup>5</sup>, has matured and developed in terms of

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<sup>5</sup> The most common types of solar cells are solar cells made of crystalline or conventional, traditional, first generation, or wafer silicon. This type of solar cell is made of solar wafers

technology, and there is a large-scale production capacity of crystalline silicon modules. However, current crystalline silicon technologies also have inherent technical limitations, the most important of which include high processing complexity and low inherent light absorption. High intrinsic light absorption requires a thick silicon wafer. The strength and weight of the glass-encased crystalline silicon modules help balance the cost of the system.

Companies that manufacture crystalline-silicon modules and their component cells and materials are motivated to pursue remaining opportunities to make this technology more competitive by improving efficiency and reducing manufacturing and material costs. Therefore, government support for research and development in the current crystalline-silicon technology is not justified.

Limitations in the availability of crystalline-silicon have led to research into thin-film photovoltaic alternatives. Commercial thin-film photovoltaic technologies, mainly cadmium telluride and indium gallium diselenide solar cells, account for approximately 10% of today's photovoltaic market and are already economically competitive with silicon. Some commercial thin-film technologies are dependent on rare elements, making it difficult to achieve practical terawatt-scale electricity generation. For example, the abundance of tellurium in the earth's crust is estimated to be only one-fourth that of gold. A number of emerging thin-film technologies currently under investigation employ new materials and structures and have the potential to provide better performance with lower manufacturing complexity and cost [18]. A number of these technologies use materials abundant on Earth. Other features of some of the new thin-film technologies include low weight and compatibility with mounting in flexible forms, resulting in lower system balance costs along with lower module cost.

### Concentrated solar power (solar thermal power plant)

One promising solution that is gaining increasing appeal is concentrated solar energy, also known as solar thermal energy. As a renewable energy technology, concentrated solar energy offers tremendous potential to meet our energy needs while minimizing environmental impact. As the name of this technology suggests, the goal is to collect and concentrate solar rays so that useful things can be done with it.

This technology (except for its dished version, which is described below) is usually used for large-scale, urban power generation. Unlike traditional photovoltaic cells that directly convert sunlight into electricity, in with a thickness of 160 to 190 micrometers, which are slices of solar grade silicon.

concentrated solar power the sun's heat is absorbed and stored. This heat can be absorbed by a fluid such as water, industrial oils, air or solid materials such as rock. The absorbed heat energy can start an electricity generation cycle, which is a power plant that produces electricity from the heat of the sun (concentrated solar power plant). The heat needed in electricity generation plants is provided by various methods, including coal burning, natural gas, nuclear reaction, etc. As mentioned, this heat can also be provided by a solar power plant. The selection of the names of the types of these power plants is based only on the way of supplying thermal energy, otherwise the continuation of the electricity production process is common to all of them.

Advances in concentrated solar energy technologies not only enable us to generate clean electricity, but also provide opportunities to incorporate thermal energy storage. By integrating thermal energy storage systems, excess heat generated during peak solar radiation can be stored in phase change materials. This stored energy can then be released during low sunlight or at night, ensuring constant electricity production. There are several technologies associated with concentrated solar energy, each with its own unique functions and benefits. The device that collects solar thermal energy is called a collector, which has different types. Some of these technologies, each of which uses its own collectors, are summarized as follows:

Parabolic solar collector systems: This system consists of large, curved mirrors that focus sunlight onto a long receiver tube that is located along the focal line of the mirrors. A heat transfer fluid flows inside the receiver tube and absorbs concentrated sunlight to produce water vapor in later stages. The turbine of the power plant moves with the help of this steam with high temperature and pressure to generate electricity. This technology is widely used in large-scale and municipal power plants due to its proven efficiency.



*Figure 20: A solar parabolic collector in California, USA*

Solar power towers: These towers use a set of mirrors called heliostats to focus sunlight on a central receiver located at the top of the tower. Focused sunlight heats a fluid in the receiver. This thermal energy can be used to produce electricity, which is almost the same process of producing electricity with other power plants. This process is explained in the previous sections. The advantage of this technology lies in its ability to achieve higher temperatures and thus higher energy conversion efficiencies.





*Figure 21: A heliostat solar power tower*

Linear Fresnel reflectors: Linear Fresnel reflectors use flat mirrors to focus sunlight onto a receiver tube. These mirrors are arranged in long, parallel rows and follow the movement of the sun throughout the day. The absorbed heat is used to generate electricity similar to the previous explanation. Linear Fresnel reflectors are cheaper due to simpler construction.



*Figure 22: A concentrated solar power plant of linear Fresnel type*

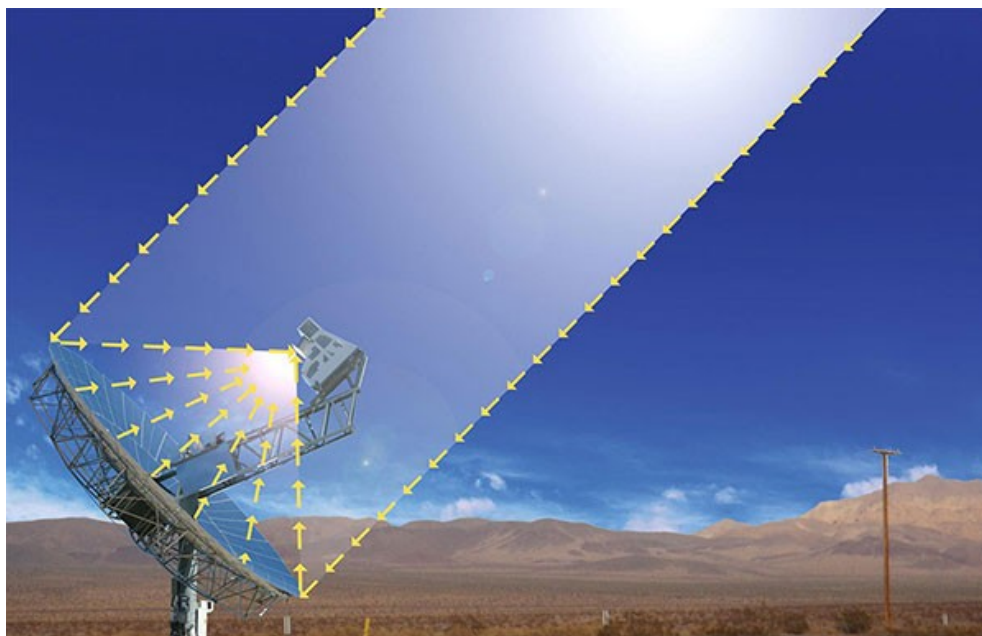
Stirling dish systems: Stirling dish systems consist of a parabolic dish that reflects sunlight to its focus. A heat receiver is located in the center of this dish and contains a Stirling motor. The engine uses the absorbed heat to drive the piston. Thermal energy is converted into mechanical energy and then into electricity through a generator. These systems are particularly suitable for small-scale applications, such as off-grid power generation or remote locations.





*Figure 23: A concentrated solar power system of the dish type*





*Figure 24: The process of concentrating sunlight in a concentrated solar power system at its parabolic focus, dish type*

Concentrated solar power systems can be deployed on a large scale without facing problems in the supply of raw materials. Also, the ability to include thermal energy storage in these systems means that concentrated solar power can be a dispatchable power source. Dispatching is used in large power plants and power networks such as power plants and controls all parts in these power plants, including production, transmission and distribution. At times when electricity is needed and the electricity system faces a shortage, the required electricity can be supplied from the stored heat. The best ways to improve the economic costs of concentrated solar power are probably higher operating temperatures and more efficient solar energy collection methods.

Therefore, research and development expenditures in concentrated solar power technology should focus on improvements in system design and solar energy capture. For example, work on systems such as solar towers, and in materials science operating at higher temperatures, and developing systems for energy harvesting can be very useful.

Concentrated solar power holds promise as a sustainable energy solution and offers numerous environmental benefits. By using this clean, abundant, and renewable resource, we can reduce our dependence on fossil fuels, reduce greenhouse gas emissions, and mitigate climate change. With ongoing research and development, the efficiency, affordability and

scalability of concentrated solar power systems continue to improve, solidifying their position as a key player in the clean energy future.

## Applications of solar energy

For centuries, humans have used this abundant and renewable energy source for various applications. With technological advancements, solar energy has emerged as an efficient and sustainable solution to meet ever-increasing energy needs while mitigating environmental concerns. Today, solar energy has found many new and increasing applications in different sectors. Some of these applications are briefly categorized as follows:

1- Electricity production: the applications of this field are very diverse because today most of the devices and devices work with the help of electrical energy.

I) Photovoltaic systems: Photovoltaic systems, which are also known as solar energy systems, have wide applications in different sectors. Some of these main applications are: as a solar panel farm, use in remote locations, self-sufficient power systems, space applications, building needs, military and transportation applications. These uses and some other examples are explained below:

a) Residential: Photovoltaic systems can be used in residential buildings to generate electricity for domestic needs. They can provide electrical appliances, lighting, heating and cooling, reducing dependence on the national electricity grid and the cost of energy bills. Photovoltaic panel solar farms can provide power on a practical scale, from tens of megawatts to more than one gigawatt. These large systems, using fixed panels or solar trackers, feed electricity into municipal or regional grids. Photovoltaic materials can also be integrated into a building's structure as windows, roof tiles, or cladding to both generate power and serve as a utility structure. Also, canopies and parking structures can be covered with photovoltaics to provide shade and power.

b) Commercial and Industrial: Photovoltaic systems are widely used in commercial and industrial environments to offset energy consumption. Appropriate arrays of solar panels can be installed on rooftops, parking lots, or open spaces to generate clean energy for offices, factories, warehouses, and shopping centers.

c) Off-grid systems: Photovoltaic systems are valuable in remote areas where there is no access to the power grid. Together with energy storage solutions such as batteries, these systems provide an independent power supply for lighting, communication devices, water pumps, military applications, remote bases and other essential appliances.

d) Grid-connected systems: Photovoltaic systems can be combined with the power grid, which allows excess power to be fed back into the grid. This allows users to earn credit through net metering or feed-in tariffs while ensuring a stable power supply during cloud periods or high demand conditions. Net metering is a system where solar panels or other renewable energy generators are connected to a public power grid and excess power is transferred to the grid, allowing customers to offset the cost of electricity taken from the grid.

e) Agriculture: Photovoltaic systems have found applications in agriculture, such as irrigation systems, water pumping and livestock operations. Solar fences, warehouse or stable lighting, and automatic feeding systems can also be implemented using photovoltaics.

f) Transportation: Solar panels integrated into electric vehicles, including cars, buses, airplanes, and bicycles, can help charge the vehicle's battery and increase its range. Solar charging stations along highways or in parking lots can also support the adoption of electric vehicles.

g) Water purification: Photovoltaic systems can be combined with water purification technologies such as reverse osmosis or UV disinfection. The use of solar energy water purification systems are especially useful in areas with limited access to drinking water.

h) Portable applications: Solar chargers, portable solar panels and solar backpacks are popular and practical for charging mobile devices, laptops and camping equipment. These programs can provide stable power in external environments.

i) Natural disaster relief: In emergencies or natural disasters, photovoltaic systems play an important role in providing temporary electricity to critical infrastructure such as hospitals, emergency response units and relief camps. In these cases, normal power sources are usually interrupted.

j) Space applications: Photovoltaic systems are widely used in space missions to supply energy to satellites, spacecraft and the International Space Station. Solar panels absorb sunlight in space and convert it into electricity to support various operations. These panels are widely used in various space missions and satellites to provide energy for communication systems, scientific instruments, propulsion systems and other onboard

equipment. Due to the abundance of sunlight available in space, photovoltaic panels provide a sustainable and renewable energy source that reduces dependence on other limited resources and minimizes the environmental impact of space exploration. Additionally, the compact and lightweight nature of these panels makes them ideal for space applications where weight and size constraints are critical factors. In general, photovoltaic panels are vital in providing energy for spaceflights, enabling long-duration flights, facilitating research efforts, and expanding our understanding of the universe beyond Earth's borders.

k) Military applications: Photovoltaic panels, especially their thin and light type, have various military applications, including providing the required power for soldiers by charging batteries and starting essential equipment. Soldiers are stationed at remote military installations, providing self-sufficient power generation for lighting, communications systems, and surveillance equipment. Photovoltaic panels power unmanned systems such as drones and ground vehicles, extending their mission time without the need for refueling or battery replacement. These panels provide portable power sources for battery charging of handheld devices and radios, and support field communications by powering radio repeaters, satellite terminals, and mobile command centers. In addition, their deployment increases energy independence and reduces dependence on external power grids.

II) Thin film photovoltaic cells: Thin film solar cells are a type of photovoltaic cell that use thin layers of semiconductor materials such as amorphous silicon to convert sunlight into electricity. Due to their flexibility and thinness, they have many applications.

III) Concentrated solar energy or solar thermal energy systems: These systems use mirrors or lenses to focus sunlight on the solar energy receiver, which converts it into heat. The heat is then used to generate electricity through steam turbines or other heat engines. These systems are usually used for the production of electricity on a rural and urban scale.

2- Solar heating: Solar heating is an environmentally friendly way to use the sun's free energy to heat homes, buildings, industrial devices, etc. The way these systems work in absorbing the sun's heat is similar to the absorption of heat in concentrated solar power plants, which was explained. Solar air heating systems collect the sun's radiation and use it to heat air or any other fluid such as water that can be used for space heating or industrial processes. These systems are often used in buildings, greenhouses, drying applications, solar desalination and solar cooking.

3- Solar cooling: Solar cooling systems use solar energy to provide cooling and air conditioning. These systems are designed to reduce dependence on the national electricity grid and reduce carbon emissions associated with conventional cooling technologies. These systems first absorb the heat energy of the sun and provide cooling for homes, offices and industrial facilities after going through processes.

4- Solar fuels: Solar fuels are a promising solution in the search for clean and sustainable energy sources. Solar fuels refer to fuels that are produced through direct or indirect conversion of solar energy such as photovoltaic or photoelectrochemical systems. This technology uses solar energy to perform chemical reactions to produce usable fuel. Using solar energy, these fuels have several advantages. First of all, solar fuels are a carbon-free alternative to conventional fossil fuels and help reduce the adverse effects of greenhouse gas emissions and climate change. Unlike fossil fuels that release carbon dioxide when burned, solar fuels only produce water and oxygen, so they are environmentally friendly and compatible with the circular economy<sup>6</sup>. Another significant advantage of solar fuels is their potential for energy independence. By capturing and storing solar energy in the form of fuel, we can reduce our dependence on limited and often geopolitically sensitive fossil fuel sources. In addition, solar fuels have considerable versatility in terms of their applications. Hydrogen is one of the most popular solar fuels that can be easily stored and used in a variety of industrial processes and power generation systems. Other solar fuels include methanol, ammonia, synthetic natural gas, carbon-based fuels such as gasoline, diesel, and jet fuel, alcohols, and sulfur-based fuels such as hydrogen sulfide. Solar fuels such as hydrogen can also be integrated into existing energy systems and facilitate the transition to a sustainable and decentralized energy grid. The development of solar fuel technologies has seen significant progress in recent years. Researchers are exploring different approaches, such as artificial photosynthesis, which mimics the natural process of photosynthesis to convert sunlight, water, and carbon dioxide into fuel. Materials engineering plays an important role in the design and optimization of efficient solar fuel devices, including photovoltaics, catalysts, and photoelectrodes. While solar fuels have great potential, their large-scale deployment still faces challenges. Research and development efforts are focused on improving the efficiency, durability and affordability of solar fuel technologies. In addition, building a strong infrastructure for the production, storage and distribution of solar fuels is essential to ensure their widespread adoption. Overall, solar fuels offer an

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<sup>6</sup> Circular economy is a regenerative system in which resources are used as long as possible, waste is minimized and materials are continuously recycled.

exciting path to a cleaner and more sustainable energy future. These fuels, using the power of the sun, are a solution compatible with the environment.

They provide zero and carbon neutrality to meet our energy needs. Continued advances in solar fuel technologies promise to transform our energy landscape and empower us to create a more resilient and sustainable world for generations to come.

5- Passive solar design: Passive solar design is architectural techniques to maximize the use of sunlight for heating, cooling and lighting of buildings. The goal is not to use mechanical systems, which need to be purchased and used, which requires cost and energy. Features such as large south-facing windows, thermal mass and awnings help optimize energy efficiency. Key elements of passive solar design include orientation, glazing and insulation, thermal mass, shading, ventilation and lighting. To place the windows of the building in the direction of the sun to receive maximum sunlight. Glass and insulation, for example, the use of low consumption windows and insulation to prevent heat loss in colder seasons and maintain cool air inside buildings in hot months. Thermal mass, for example, the use of materials with high heat storage capacity, such as concrete or stone, to absorb and slowly release heat to stabilize the temperature inside the building. Shading such as the implementation of projections, canopies or vegetation to control the amount of direct sunlight that enters the building in the hot seasons and prevent overheating. Ventilation means ensuring adequate air flow through the placement of windows, vents and thermal chimneys to facilitate natural cooling and reduce dependence on mechanical systems. Lighting is to maximize the penetration of natural light through windows, skylights and skylights that minimize the need for artificial light. By using these passive techniques, buildings can reduce energy consumption and increase occupant comfort, contributing to sustainability and energy efficiency goals.

In the following, we will further investigate solar energy from different aspects, which is necessary for a better understanding of this type of energy and decisions.

### Photovoltaic installation

The recent significant growth in the use of photovoltaic systems is due to the reduction of at least 50-70% of reported photovoltaic prices (in the United States of America without federal subsidies) per installed peak watt [23]. Almost all of these improvements are the result of reduced prices of modules and inverters. In addition, the structure of the solar energy market,

especially at the residential level, is changing with the evolution of new business models, the introduction of new financing mechanisms, and the impending reduction of subsidies in various countries around the world.

### Solar economy

The economic competitiveness of solar electricity compared to other electricity generation technologies depends on its cost and output value in the electricity market. A measure that is usually used to compare different sources of electricity is the levelized cost of electricity [24]. However, the levelized cost of electricity is an insufficient measure to assess the competitiveness of photovoltaics, or to compare photovoltaics with concentrated solar power or conventional generation sources. Because the amount per kilowatt-hour of photovoltaic generation depends on many characteristics of the regional electricity market, including the level of photovoltaic penetration. For example, the more photovoltaic capacity there is in a given market, the less valuable it is to increase photovoltaic generation.

### Solar utility scale

Nevertheless, estimates of the levelized cost of electricity are useful because they provide a rough idea of the competitive position of solar energy at its current low level of penetration in the electricity supply mix. In the economic evaluation of utility-scale solar generation, an appropriate point of comparison is with other utility-scale generation technologies, such as natural gas combined cycle power plants [25]. For example, without taking into account the cost of carbon dioxide emissions and federal subsidies in the United States, current industrial-scale photovoltaic electricity has a higher levelized cost of electricity than combined cycle natural gas generation in most regions of the United States, including relatively sunny regions. It's like Southern California.

Designing concentrated solar power plants with thermal energy storage reduces the levelized cost of electricity and allows these plants to produce electricity at times when electricity is most valuable, making them more competitive with other sources of electricity generation. However, utility-scale photovoltaic generation is about 25% cheaper than concentrated solar power generation.



## Residential solar

If solar generation is valued for its share at the system or wholesale level, and assuming that solar penetration into the grid does not cause a net increase in distribution costs, residential PV generation is on average about 70% more expensive than large-scale PV generation. - It is beneficial. Now, even in California, and even with 100 percent effective federal subsidies, residential PV is not competitive with natural gas combined cycle generation on a levelized cost of electricity basis.

Lowering the balance of system costs to more typical levels of PV installations in Germany brings residential PV closer to a competitive position, but residential PV is still more expensive than photovoltaic generation or city-scale natural gas combined cycle power plants.

In most electricity distribution systems, generation is offset by grid-connected residential photovoltaic systems under a process called net metering. In this flow, the owner of the residential PV installation pays the residential retail rate for electricity purchased from the local distribution company and is compensated at the same rate for any excess PV output fed back into the grid.

In this situation, a commonly used investment criterion is grid parity, which is achieved when it is equally attractive and cost-effective to use a rooftop photovoltaic system to meet a portion of a residential customer's electricity needs.

## Combining electricity produced from photovoltaic solar energy with existing power plants

### *Distributed use of solar energy*

The use of photovoltaic electricity in a distributed manner (for example, residential buildings in different parts of the city are equipped with photovoltaic electricity generation systems) imposes costs on the system in two ways. In general, electrical energy losses in the transmission network are initially reduced by increasing the use of distributed photovoltaic electricity. However, when using more distributed photovoltaic energy and increasing a significant share of the total production, it causes the distribution costs to increase. As a result, local rates will also increase, because additional investments are needed to maintain the quality of electricity, because the currently used networks are not designed to manage and organize the return of electricity from customers to the grid [26]. Currently, electricity storage is not at all a cheap alternative to grid reinforcement or distributed photovoltaic power surge management upgrades.

In an accurate, efficient and fair distribution system, each customer pays a share of the costs of the distribution network, which reflects his responsibility for creating these costs. Instead, most U.S. utilities categorize distribution network costs, electricity costs, and other costs and then charge a flat rate per kilowatt-hour that just covers all of those costs.

This change in costs and subsidies for residential solar generators has already led to political conflicts in some regions and states of the United States of America. It is expected that these conflicts will intensify with the increase in the use of solar energy in residential houses. Because of these problems, rapid and long-term growth in distributed solar power generation is likely to require consideration and development of pricing systems that lead to efficient and fair investment in the grid.

### Wholesale and macro markets for solar energy

Concentrated solar power generation, when combined with thermal energy storage, can be used and dispatched in the same way as thermal or nuclear power generation in electricity markets.

However, when PV power has a significant share of the wholesale electricity market, coordination and dispatching challenges arise. In nearly two-thirds of the United States and many other countries, generators auction their electricity generation to competitive wholesale markets. Photovoltaic units offer an auction with their final cost of production, which is zero, but on the other hand, they earn the final cost and profit of the system every hour.

In wholesale electricity markets, it replaces the systems of conventional electricity producers (e.g. fossil fuels) that have the highest fluctuating costs. This reduces variable production costs and thus lowers market prices. And since older, conventional systems depend on fossil fuels, this also results in lower carbon dioxide emissions.

It is likely that in the future, the combination of non-solar energy generation with large volumes of solar energy at maximum capacity will be adjusted more flexibly. Therefore, the economic value of photovoltaic output can be expected to increase. Also, net load peaks can be reduced and cycle requirements on thermal power generators can be reduced by coordinating solar power generation with hydroelectric power, pumped storage, other available types of energy storage, and demand management techniques. Because of the potential importance of energy storage in facilitating greater use of solar energy, large-scale storage technologies are attractive subjects for R&D spending.

It is not cost-effective to use photovoltaic energy at low volumes, even if it becomes cost-effective to produce this energy at low penetration levels, the revenue per kilowatt of installed capacity decreases as solar penetration increases until a break-even point is reached, beyond which the investment Most of the solar photovoltaic energy will be useless. Therefore, a significant reduction in costs is needed to make the photovoltaic system competitive in a very large volume of use, which is foreseen in many plans to reduce carbon dioxide production.

In systems that require long-term energy storage, such as hydropower plants with large reservoirs, this solar penetration is reduced. As opportunities for new hydroelectric power generation or pumped storage are limited, breaking the barrier to high solar power usage further highlights the importance of development. Economical technologies of multi-hour energy storage are also an excellent approach to use cost-effective photovoltaic energy on a large scale.

### Establishing and using the technology of solar energy

Reasons cited to support the allocation of subsidies for current solar technology usually include short-term greenhouse gas emission reductions and job creation. However, the main goal should be the large-scale, long-term growth of solar power generation as a way to achieve significant reductions in future greenhouse gas emissions as well as to meet the growing global energy demand. In the second stage, the main goal is to achieve these two goals with the most effective use of budget and public capital and private resources. The least expensive way to promote solar energy is through one of several price-based policies that reward solar energy output according to its value to the electricity supply system.

Subsidies for solar technologies are far more effective per taxpayer dollar spent if they reward production than investment. This change corrects some inefficiencies, whereby a kilowatt-hour of electricity produced by a residential photovoltaic system is subsidized much more than a kilowatt-hour of electricity produced by another city-scale power plant nearby. receives.

### A final approach

Facing the challenge of global warming, solar energy has great potential to meet human energy needs in the long term while reducing greenhouse gas emissions in terms of the environment. Solar energy has recently become a reliable and fast-growing source of electricity generation in some parts of

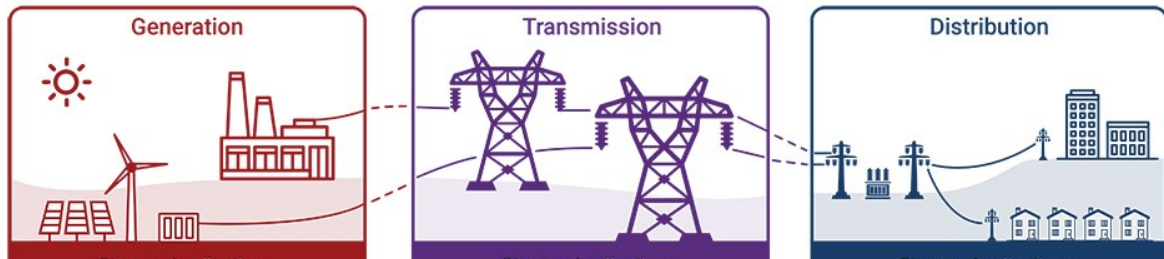
the world, with its development aided by federal, state, and local policies in the United States, as well as government support in Europe, China, and elsewhere. has taken. Today, compared to other energy technologies, the solar industry is developing and expanding with much greater growth, and as a result, it can play a very important role in the global energy system by the middle of the century. As mentioned, the International Energy Agency has predicted that the growth rate of solar energy is so high that the share of the world's energy supply through solar energy will surpass all other sources by 2027 and reach 22.2%. Although this resource is not available for all parts of the world in the same, plentiful and affordable way.

Although the cost of using solar energy has decreased significantly in recent years and its market penetration and use has grown, its large-scale use is expected to increase in the coming decades. The solar industry's ability to overcome several obstacles depends on it. These barriers can include cost, intermittency, availability of technology and raw materials, and successful integration of the large-scale system into existing electrical systems. In general, government policies play an important role in overcoming these challenges. But research and development on solar energy technologies have shown that all obstacles are being removed. The costs of these systems are always decreasing. Suitable technologies for intermittent solar energy have been properly developed. For the problem of intermittency, systems such as generators based on fossil fuels and hydropower plants can be combined with solar energy systems so that whenever the solar energy decreases, these systems compensate for the energy. Investigations carried out so far show that raw materials are not difficult to obtain and that large-scale development and integration are possible. Especially if a penalty for carbon dioxide production and environmental degradation of fossil fuels is considered, renewable energies become completely affordable and prioritized, otherwise the affordability of this energy as well as other Renewable energies are facing challenges in some countries. Among renewable energies, in general, solar energy is more abundant and available than other energies. For example, in recent years, problems related to dam construction capacity limitations, political tensions and water shortages between countries have jumped to start hydroelectric power plants.

In general, the rapid growth of solar energy and the world's transition to green energy largely depends on policymakers to make a serious decision to price the carbon emission penalty and implement the right policies. The risks and challenges posed by global climate change and warming, and the potential for solar energy to play a major role in managing these risks and

challenges, may not be reason enough to modify and sustain efforts by law enforcement and the private sector to support solar energy technology.

## Transmission, storage and distribution of energy



*Figure 25: Generation, transmission and distribution of energy*

### Introduction

As the demand for energy continues to grow, it is necessary to discover efficient ways to extract, transmit, store and distribute energy. The energy supply process includes energy extraction, energy storage, energy transfer and energy explanation. These play essential roles in ensuring an efficient and reliable supply of energy to meet the growing global demand. A complex network is very important to facilitate the seamless transfer of energy from production sources to consumers, enabling efficient use and utilization of different energy sources.

Energy distribution is an essential aspect of the modern energy landscape, enabling the widespread access and consumption of different types of energy. From electricity grids to natural gas grids, district heating systems and the integration of renewable energy sources, efficient distribution systems ensure a reliable and sustainable energy supply. By continuously improving and innovating these systems, we can optimize energy use, reduce environmental impacts, and bring the benefits of energy to all humans.

It is noteworthy that energy transfer refers to the movement of energy from one system or body to another system or body, which is transferred in the form of heat due to temperature differences. These methods are conduction, convection and radiation, which have been explained in the previous parts of this chapter. Matter is needed for energy transfer by conduction and convection, but matter is not needed for radiation method. For example, solar energy passes through millions of kilometers without a vacuum and enters the earth through the method of radiation without the need for matter. But energy transmission has another concept that is discussed in this section [27].

In the previous parts, it was explained about the way of generation, extraction and conversion of energies. In this section, we will examine more energy distribution issues, including transmission and energy storage, in a categorized manner.

## Energy Transmission

It refers to the movement of energy over longer distances. For example, transporting crude oil through pipelines between cities and countries. This transportation enables the distribution of energy from the point of production to the point of consumption. It includes different types of electrical, thermal, mechanical and chemical energy. Whether through power cables, pipelines or transportation systems, energy transmission ensures that energy is transported to power plants, industrial facilities, residential areas and beyond. There are different methods for energy transfer, each of which has its own characteristics, advantages and applications [28].

### Electric energy transfer:

Electricity is the most common form of energy transfer worldwide. In this method, energy is transmitted through power lines and cables and is accessible for lighting, heating and powering various devices. Power grids enable efficient transmission and distribution of electricity over large distances. For example, high voltage transmission lines carry electricity generated in power plants to substations and then distribute it to residential and commercial areas.

Advantages: efficient over long distances, the possibility of easy control and regulation of electric current, easily converted into other forms of energy such as mechanical energy, thermal energy, etc. through motors.

Disadvantages: Power losses occur over very long distances due to resistance, without proper infrastructure maintenance it is prone to blackouts and interruptions in energy transmission.

### Pipeline transfer:

For oil, natural gas, and other hydrocarbons, pipelines serve as the primary means of transportation. This method is usually used for long distance shipping. These networks transfer energy resources from extraction points to refineries or distribution centers. The Trans-Alaska Pipeline System is a pipeline that transports crude oil from the North Slope of Alaska in the United States of America to the coastal areas of Valdez, 1,287 km long.



Natural gas is an efficient energy source for heating, cooking, and power generation, as well as efficient distribution systems. Natural gas pipelines form an extensive network that connects natural gas producers to distribution centers and end consumers. These pipelines carry gas under high pressure, allowing it to flow over long distances, often crossing international borders.

Advantages: Efficient and cost-effective for transporting large quantities of liquids, reducing the risk of spills and accidents compared to other methods via truck. Disadvantages: having a relative limitation to certain materials that are difficult to transport through pipes. Initial installation and maintenance is expensive and time-consuming.

Wireless energy transfer:

Wireless or remote energy transfer technologies are emerging as a potentially world-changing change. Their purpose is to transmit energy without the need for physical connections, the use of electromagnetic fields or the induction of resonance. Nikola Tesla's pioneering work in the field of wireless power transmission laid the foundation for future innovations in this field. Some of these technologies include: radio waves, inductive charging, microwave power transmission and solar energy satellites.

Radio waves are used to transmit signals for various electronic devices such as radios, televisions, and wireless Internet connections. Inductive charging technology is commonly used in wireless charging pads for smartphones and other devices. It uses electromagnetic fields to transfer energy between two coils, one in the charging pad and the other in the device. Microwave power transfer involves the use of microwaves to transfer energy from a power source to a device. This method has been used experimentally to transfer energy over long distances and can potentially be used for wireless charging of electric vehicles in the future. Solar energy satellites, satellites that are theoretically equipped with large solar panels that can generate electricity from the sun. This energy is converted into microwaves and sent to earth for use, but so far this has not been done.

## Energy storage

As mentioned, some energy sources are intermittent in nature. Energy storage is very important to solve this problem and ensure continuous power supply. Here are some examples of energy storage technologies [29]:

Battery storage: Batteries store energy in chemical form and convert it into electricity when needed. They are used in portable devices, electric vehicles

and grid-scale storage systems. It should be noted that lithium-ion batteries are widely used due to their energy density and high efficiency.

**Pumped water storage:** One of the most common storage methods is pumping water to high altitudes when we don't need energy. When the energy is needed, it can be converted into electricity as a stored gravitational potential energy and supply periods of high demand for electricity such as noon. This technology provides massive storage capacity and helps stabilize the power grid.

**Hydrogen storage:** Hydrogen can be used as an energy carrier and stored in underground tanks. It can be produced through electrolysis of water using excess electricity and later used to generate electricity through fuel cells or combustion.

**Thermal storage:** Thermal energy can be stored and later converted into electricity or used as a direct heat source. For example, using molten salt to store heat from solar thermal power plants or using phase change materials to store and release heat for heating systems.

**Superconducting Magnetic Energy Storage:** These systems store energy in the magnetic field created by a superconducting coil. If needed, the stored energy can be released by converting magnetic energy into electrical energy.

### Integration of renewable energies:

With the expansion of renewable energy sources such as solar and wind energy, the integration of these intermittent energy sources helps to provide a uniform supply of energy to the grid. Advanced energy distribution systems enable efficient management and distribution of renewable energy by balancing intermittent supply and demand. For example, smart grids use real-time data and digital technologies to monitor and manage the flow of electricity across the distribution network, ensuring that additional renewable energy is incorporated into the grid when available and fills energy gaps.

### Conclusion:

Efficient energy transmission, storage and distribution systems are critical components of a sustainable energy framework. By understanding and developing these technologies, we can optimize energy consumption, reduce losses, and build a cleaner and more reliable energy infrastructure. Embracing these developments will lead us to a future where energy needs are met and planet Earth is preserved for future generations.

